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Evaluation and Control of Sidestreams Generated in Publicly Owned Treatment Works

Roy F. Weston, Inc.
West Chester, PA

Prepared for

Municipal Environmental Research Lab.
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EVALUATION AND CONTROL OF SIDESTREAMS GENERATED IN PUBLICLY OWNED TREATMENT WORKS

by

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EPA Contract No. 68-02-2775

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16. ABSTRACT

This document provides methodologies and considerations for the evaluation and control of sidestreams generated in publicly owned treatment works (POTW's). The methodologies are structured in algorithms that provide guidance for the determination and control of the sidestream impacts.

The algorithms are used initially to determine whether one or more sidestreams are affecting the primary and secondary mainstream process performance. Once an impact of the process performance is determined, additional algorithms are provided that present operational means of controlling the impact of the sidestream, either at the mainstream process or at the source of the sidestream.

In addition, sidestream characterization data are appended to this report to provide available information for design purposes.

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communication link between the researcher and the user community.

Many of the publicly owned treatment works (POTW's) in the United States do not meet the effluent standards for which they were designed. In many cases, sidestreams produced as a result of various sludge handling processes have been implicated as a major cause of the POTW performance problem. This research project evaluated the impact of sidestreams on POTW mainstream processes. Procedures were developed for determining if sidestreams are the cause of performance problems at a POTW. Once sidestreams are determined to be a problem, operational procedures to minimize the impact of sidestreams are presented. Design information relative to consideration of sidestreams in POTW design are presented.

Francis T. Mayo, Director
Municipal Environmental Research
Laboratory

ABSTRACT

This document provides methodologies and considerations for the evaluation and control of sidestreams generated in publicly owned treatment works (POTW's). The methodologies are structured in algorithms that provide guidance for the determination and control of the sidestream impacts.

The algorithms are used initially to determine whether one or more sidestreams are affecting the primary and secondary mainstream process performance. Once an impact of the process performance is determined, additional algorithms are provided that present operational means of controlling the impact of the sidestream, either at the mainstream process or at the source of the sidestream.

Through the proper use of the algorithms, a point is reached where all applicable operational methods to reduce the sidestream impact have been performed. If, after reevaluation of the process, the sidestream continues to have a negative impact on the process performance, design modifications are suggested to reduce the impact.

In addition, sidestream characterization data are appended to this report to provide available information for design purposes.

The methodologies presented in this report for the evaluation and control of sidestreams in POTW's are not intended to represent all of the available means, nor are they each intended to apply to all POTW's. The algorithm format is intended to be flexible so that it can be tailored and applied to the individual POTW.

This report was submitted in fulfillment of Contract No. 68-02-2775 by Roy F. Weston, Inc. under the sponsorship of the U.S. Environmental Protection Agency. The report covers the period 2 January 1979 to 31 December 1980, and work was completed as of 31 December 1980.

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The original concept for the project and funding came from the Plant Operation and Design Program under the direction of Jon H. Bender, U.S. Environmental Protection Agency Project Officer. Major input was provided by the Urban Systems Management Section, John M. Smith, Chief.

SECTION 1

INTRODUCTION

PURPOSE

Publicly owned treatment works (POTW's) have been mandated by the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500) and the Clean Water Act of 1977 (Public Law 92-215) to achieve certain levels of wastewater treatment. To achieve adequate treatment levels, either the treatment efficiency of existing facilities must be increased or new processes must be added. In general, an upgraded facility or a new facility generates many types of sludges and increases the total quantity produced. This results in many types of sludge handling or treatment operations and processes being required to ensure proper overall system performance. In addition to producing a sludge that must be adequately disposed, a sidestream is generated that must be treated.

Many performance problems at POTW's are allegedly the result of the recycling of these sidestreams within the POTW. Sidestreams often carry significant quantities of organic and inorganic materials either in solution or suspended form. Although the volume of these sidestreams is small in comparison with the forward flow of the POTW's, the return of sidestreams to the head of a POTW can increase the organic loading to the POTW by as much as 50 percent, with similar increases in the solids loading. However, these are extreme cases, and generally most mainstream processes should be capable of handling any sidestreams generated at a POTW.

The purpose of this document is to characterize the sidestreams generated by the various sludge handling/treatment processes, and to develop operational and design information which can be used to abate the effects of these sidestreams on mainstream processes in existing and new POTW's.

This document has been prepared for use by persons engaged in the operation of POTW's and in the selection/design of POTW treatment processes and their related facilities. Included are design modifications, upgrading, and new facility design.

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All work has been directed toward the following processes and operations:

1. Mainstream treatment processes:
    - Primary clarification (P)
    - Activated sludge (AS)
    - Trickling filter (TF)
    - Rotating biological contactor (RBC)
2. Sidestream generator/sidestream:
    - Gravity thickener (GT)/supernatant
    - Dissolved air flotation (DAF)/subnatant
    - Anaerobic digestion (AnD)/supernatant
    - Aerobic digestion (AeD)/supernatant (decant)
    - Vacuum filter (VF) filtrate
    - Centrifuge (C)/centrate
    - Belt filter press (BF)/filtrate
    - Sand drying bed (SB)/under-drainage liquor
    - Sludge lagoon (LA)/supernatant
    - Heat treatment (HT)/liquor
    - Wet air oxidation (WAO)/liquor
    - Pressure filter (filter press) (FP)/filtrate
    - Purifax (PX)/supernatant, filtrate, subnatant, or underdrainage liquor

These mainstream treatment processes and sidestream generators are incorporated in an evaluation matrix presented in Table 1. The evaluation matrix is prioritized in order of cost of sidestream control and treatment. The matrix elements in Table 1 labeled "No evaluation required" are those below the prioritization limit.

Information presented in this document includes:

1. Characterization of sidestreams.
2. Algorithms and methodology used for mainstream process evaluation.
3. Algorithms and methodology used to develop mainstream and sidestream operational controls to abate the impact of sidestreams return on mainstream processes.
4. Matrices of design modifications for application to existing facilities. (This also serves as a checklist for items to be considered in new designs.)

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TABLE 1. PROCESS MATRIX

Sidestream Generator	Treatment Process: Primary (P)	Activated Sludge (AS)	Trickling Filter (TF)	Rotating Biological Contactor (RBC)
Gravity Thickener (GT)	○	●	●	●
Dissolved Air Flotation (DAF)	○	●	●	●
Anaerobic Digestion (AnD)	●	●	●	●
Aerobic Digestion (AeD)	○	●	○	○
Vacuum Filter (VF)	●	●	●	●
Centrifuge (C)	●	●	●	●
Belt Filter Press (BF)	●	●	●	●
Sand Drying Bed (SB)	●	●	●	●
Lagoon (LA)	○	●	●	●
Heat Treatment (HT)	●	●	●	●
Wet Air Oxidation (WAO)	●	●	●	●
Pressure Filter (Filter Press, FP)	●	●	●	●
Purifax(PX)	●	●	●	●

○ No evaluation required
● Evaluation required

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5. Design information for new facilities or upgrading/expansion of existing facilities.

ORGANIZATION

Section 2 Control of Sidestream Impacts on POTW's Mainstream Treatment Processes

This section presents:

1. A summary of a literature review performed for the characterization of sidestreams.

2. A User's Guide that presents the general information required to utilize the monitoring program, Evaluation Algorithms, Operational Control Algorithms, Design Modifications Matrix, and design guidelines presented in Sections 2 through 6. A description of each is provided along with the general methodology required for utilization. Three checklists have been developed. The first is for utilization with the Evaluation Algorithms, the second for utilization with the Operational Control Algorithms, and the third for use with the Design Modifications Matrix.

3. Process monitoring requirements which list the parameters which are to be incorporated into a general monitoring program. This monitoring program accomplishes two goals:

   - Provides the data required to determine plant performance (both overall and by process/operation) and identify problem areas (through use of Evaluation Algorithms) for a given POTW.

   - Provides actual in-plant sidestream characterization data. Presently, these types of data are practically nonexistent.

When influent, effluent, and plant schematic (or process description) are included, the data can be compared in a meaningful manner.

Section 3 Evaluation Algorithms

Three Evaluation Algorithms are presented: primary clarification, activated sludge, and trickling filter/rotating biological contactor mainstream treatment processes. The secondary processes (AS, TF, and RBC) include secondary clarification as part of the process. These algorithms enable the engineer/supervisor/operator to evaluate the mainstream treatment process in a systematic and progressive manner, the end result being the identification of problem areas.

Section 4 Mainstream (Operational) Control Algorithms

Four Operational Control Algorithms are presented for mainstream treatment processes (P, AS, TF, and RBC) to aid the engineer/supervisor/operator in mitigating the impact of sidestream return on overall POTW treatment efficiency. These algorithms present operational modifications to be made at the mainstream treatment process, with applicability dependent on site conditions. They do not recommend modifications that would change sidestream characteristics.

Section 5 Sidestream (Operational) Control Algorithms

Ten Operational Control Algorithms are presented for sidestream generators (gravity thickeners, dissolved air flotation thickening, anaerobic digestion, aerobic digestion, vacuum filters, centrifuges, belt filters, sand drying beds, lagoons, heat treatment, and wet air oxidation) to aid the engineer/supervisor/operator in modifying the characteristics of the sidestream to mitigate their impact on overall POTW treatment efficiency. These algorithms present operational modifications to be made at the sidestream generator, with applicability dependent on conditions. They do not recommend operational modifications to the mainstream treatment process.

Section 6 Design Considerations for POTW's

Design Modifications for Existing POTW's--

A matrix has been prepared which contains design modifications developed for mainstream treatment processes and sidestream generators. The design modifications are cross referenced to mainstream treatment processes, sidestream generators, and the evaluation factors (hydraulic, dissolved oxygen, suspended solids, biochemical oxygen demand, and pH). Design modifications are those which require an actual physical change to equipment or processes, such as:

1. New piping.
2. Modifications internal to existing equipment/reactors (e.g., the installation or repositioning of baffles, weirs, pumps, washwater sprays, etc.).

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3. Chemical addition.
4. Addition of equipment/reactors.

Modifications which cost $25,000 and can be completed by the POTW staff are included. The Design Modifications Matrix serves as a checklist of items to consider in the design of a new facility or the upgrading/expansion of an existing facility.

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Design Information--
Guidance to be used by engineers when selecting treatment processes, preparing designs for new facilities, or preparing designs for the upgrading/expansion of existing facilities is presented. Flow, SS, and BOD_5 loadings information has been tabulated according to sidestream generator and the mainstream treatment flow scheme in which it appears. Utilization of these guidelines and loadings ensures that the impacts of sidestreams are considered in any design. Any POTW designed in this manner should be able to adequately treat the sidestreams without degradation of overall treatment performance.

Appendix A Ranking of Process Matrix

This appendix includes the methodology and information used to determine the sidestream generator and mainstream treatment process combinations selected for detailed evaluation. Key elements include:

1. Presentation of mass balance models.
2. Presentation of prioritization equation.
3. Prioritization of the process matrix including selection of mainstream processes and sidestream generator combinations for further evaluation.

Appendix B Application Example

A complete example is presented to illustrate the methodology involved in working through the algorithms, Design Modifications Matrix, design guidelines, and appropriate checklists. The example includes sample calculations where required. The wastewater treatment process flow scheme on which the sample is based is presented and, while the values/data for POTW influent/effluent quality and individual processes operations influents/effluents/underflows are hypothetical, they are consistent with other data presented in this document.

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SECTION 2

CONTROL OF SIDESTREAM IMPACTS ON POTW's MAINSTREAM TREATMENT PROCESSES

CHARACTERIZATION OF SIDESTREAMS

General

It is desirable to characterize the various sidestreams in POTW's so that information is available to develop operating and design strategies to control the impact of the sidestreams on the mainstream treatment processes. In general, there are three ways in which these characterization data could be obtained:

1. Literature review.
2. Review of actual POTW data.
3. Sampling and analytical program.

For this document, data were obtained from the literature because there is little actual POTW data available. POTW operators typically concentrate on monitoring mainstream processes and seldom, if ever, monitor sidestreams. It is doubtful, therefore, that enough data could have been collected to determine statistical relevance.

The third possibility was eliminated due to the high costs of implementing the type of sampling and analytical program required. On a short term basis, it would be difficult to obtain representative data at a sufficient number of plants to ensure some degree of statistical relevance for the 13 sidestream generators and four mainstream treatment processes.

Summary of the Literature Search

A literature search was completed as part of this study. A bibliography of the literature searched is included as the References. Information and data were gathered on solids retention, BOD_5, and suspended solids. The ranges of values noted, along with the corresponding references, are presented in Table 2.

Methodology for Characterization

A typical POTW contains two or three sidestream generators. Models have been developed for each POTW process/operation and

TABLE 2. SUMMARY OF LITERATURE REVIEW

Sidestream Generator	Abbreviation	Numbers in Use	Solids Retention %	References	BOD$_5$ mg/L	References	SS mg/L	References
Gravity Thickening	GT	940	80-95	3,42,49,59,75	100-400	35,49,72,75	98-2,500	3,7,25,35,42,49,59,61,64, 72,74,75,77,81,108,118, 120,121
Dissolved Air Flotation	DAF	314	70-99.9	4,39,40,42,48,55, 59,60,64,75,121	50-3,950	72,75	20-2,440	4,25,39,40,42,49,55,59,60 64,67,72,75,77,81,92,108
Anaerobic Digestion	AnD	6,796			2-11,014	13,14,29,49,55,56,57, 72,75,76,87,995,100, 108,121	100-32,400	12,13,14,21,49,55,56,57, [illegible],72,75,76,87,94,95,100, 104,108,114,121
Aerobic Digestion	AeD	4,750			5-6,350	1,21,52,55,75,121	10-41,800	1,4,52,55,64, [illegible]5,121
Vacuum Filtration	VF	1,912	80-99.5	33,65,70,75,94, 96,120	10-10,000	14,55,75,108,122	160-20,000	4,14,25,26,33,36,42,47, 55,65,70,72,75,80,87,94, 96,108,114,120,121
Centrifugation	C	368	30-98	3,4,6,21,33,40,42, 49,55,72,75,83,87,94, 96,98,104,108,115,121 122	173-10,000	49,75,87,122	100-20,000	2,3,4,20,21,25,33,40,42, 49,55,72,75,83,87,94,96, 98,108,114,115,120,121,122
Belt Filter Press	BF	132	22-99.8	4,33,36,94,117,122	46-146	122	30-3,400	4,9,16,33,36,55,94,96, 117,122
Sand Drying Beds	SB	10,939	85-100	33,108	6-6,000	14,29,55,72,108	20-800	14,33,54,72,104,112
Lagoons	LA	797			150	49	71	49
Heat Treatment	HT	170	90-99^{+}	49	1,600-15,000	47,14,29,30,32,37,42, 48,49,50,55,56,72,75, 108,121	50-11,400	14,25,32,42,48,49,50,55, 72,75,87,103,108,112
Wet Air Oxidation	WAO	13	90-99^{+}	49	3,000-10,000	14,29,32,37,42,51, 55,49,72,75,108, 121	20-500	14,32,42,49,55,75,99
Pressure Filter	FP	157	96-100	18,33,75,96	1,000-6,500	25	100-1,926	4,25,26,33,42,55,75, 96,121
Purifax	PX	69			100-350	14,16,108	50-150	14,16,112,121

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are included in Appendix A. The models are designed so they can be plugged into any flow scheme as modules, and each is complete within itself. The influent to the modules is either the effluent or underflow from another process/operation of the POTW influent. With that feed the models are used to predict the effluent and underflow from that process/operation.

In order to characterize the sidestreams contained in a particular flow scheme, the appropriate models were selected based on the processes/operations present. For a detailed description of the use of the models developed for sidestream characterization, refer to Appendix A.

USER'S GUIDE

General

This User's Guide presents the general information required to use the monitoring programs, Evaluation Algorithms, Operational Control Algorithms, Design Modifications Matrix, and design information contained in this report. The algorithm, matrix, or design information is presented with an accompanying discussion. For the purposes of this report, an algorithm is defined as a procedure for solving a problem that may involve repetition of operation. The algorithms presented in this report can be likened to a logic flow diagram and, as such, the user follows the directions at each step until the goal of the process is reached.

A detailed example has been prepared and is included in Appendix B to illustrate the use of the programs, algorithms, matrices, and guidelines. Three checklists have been developed to aid the user as he works through the algorithms, matrices, and guidelines. These checklists are important because they provide the means to keep track of the status and progress of projects to characterize and control the impacts of sidestreams on existing POTW's and ensure that potential impacts are considered during the design of new or expanded/upgraded POTW's.

Process Monitoring Program

Purpose--

The purpose of this monitoring program is to provide information and data necessary to characterize sidestreams, calculate loadings, determine plant performance (overall and by process/operation), identify problem areas (mainstream treatment process Evaluation Algorithms), and aid in the selection of operational and design modifications.

General Description--

A process monitoring program must be developed by the user for the POTW to be evaluated. A detailed listing of parameters to be monitored for influent, primary clarification, secondary treatment processes, and sidestream generators is included in Table 3. The user should locate those processes/operations which are present in his wastewater treatment process flow scheme on the detailed listing and develop his own listing. All parameters are to be listed, but those which already are a part of some type of monitoring program are to be so noted. This enables the user to get a realistic idea of the sampling and analytical effort required.

Once the parameters are listed, which determines the sampling sites, a sampling program should be developed. The program should be a two-stage program, with and without sidestreams recycle. The two-stage program is necessary to obtain the proper data. When all of the components are known, it is a matter of scheduling to fit manpower, equipment, and analytical requirements.

An example process monitoring program is presented in Figure 1.

Results--

A process monitoring program will have been developed of sufficient detail to provide the proper information and data to use the algorithms, matrices, and guidelines contained in this document.

Mainstream Treatment Process Evaluation Algorithms

Purpose--

The purpose of the Evaluation Algorithms is to provide a vehicle which enables the user to take the information and data obtained during the monitoring program to:

1. Evaluate POTW performance (both overall and by individual process/operation).

2. Determine the impacts of sidestreams recycle on mainstream treatment processes.

3. Transfer to algorithms, matrices, and guidelines which identify operational controls/design modifications that are available to mitigate those impacts.

4. Allow reevaluation to determine if implemented operational controls/design modifications mitigated the impacts sufficiently.

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TABLE 3. PROCESS MONITORING REQUIREMENTS FOR SIDESTREAM EVALUATION AND CONTROL

1. Influent (w/o sidestream)

- Flow
- Total Suspended Solids, TSS
- Biochemical Oxygen Demand, BOD_5
- pH
- Dissolved Oxygen, DO

2. Influent (w/sidestream)

- Flow
- Total Suspended Solids, TSS
- Biochemical Oxygen Demand, BOD_5
- pH
- Dissolved Oxygen, DO

3. Primary Clarifier (with and without sidestream flow)

- Effluent Flow
- Effluent Total Suspended Solids, TSS
- Effluent Biochemical Oxygen Demand, BOD_5
- Effluent DO
- Effluent pH
- Sludge Pumping Rate
- Sludge Pumping Frequency
- Sludge Pumping Duration
- Sludge Total Suspended Solids, TSS

4. Secondary Treatment (AS, TF, RBC)

- Dissolved Oxygen (AS only)
- Mixed Liquor Suspended Solids
- Dissolved Oxygen Uptake Rate (AS only)
- Sludge Waste Rate
- Sludge Waste Duration
- Sludge Waste Frequency
- Sludge Total Suspended Solids, TSS
- Final Effluent Suspended Solids
- Final Effluent Biochemical Oxygen Demand, BOD_5
- Final Effluent Flow
- Final Effluent pH

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TABLE 3. (continued)

5. Gravity Sludge Thickening (each unit)

- Overflow BOD_5
- Overflow Total Suspended Solids, TSS
- Overflow Flow Rate
- Underflow Sludge Pumping Rate
- Underflow Sludge Pumping Duration
- Underflow Sludge Pumping Frequency
- Sludge Total Suspended Solids, TSS
- Feed Sludge TSS (if blended)

6. Dissolved Air Flotation (each unit)

- Effluent BOD_5
- Effluent Total Suspended Solids, TSS
- Underflow Flow Rate
- Underflow Frequency
- Underflow Duration
- Air Volume
- Recycle Flow Rate
- Thickened Sludge Flow
- Thickened Sludge SS

7. Anaerobic Digestion (each unit)

- Supernatant Total Suspended Solids, TSS
- Supernatant Flow Rate
- Supernatant Flow Duration
- Supernatant Flow Frequency
- Supernatant BOD_5
- Sludge Feed Volatile Suspended Solids
- Sludge Feed Rate
- Sludge Feed Duration
- Digested Sludge Quantity
- Digested Sludge, TSS

8. Aerobic Digestion (each unit)

- Supernatant Total Suspended Solids, TSS
- Supernatant Flow Rate
- Supernatant Frequency
- Supernatant Duration
- Sludge Settleability
- Supernatant BOD_5

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TABLE 3. (continued)

- Digested Sludge Quantity
- Digested Sludge TSS

9. Vacuum Filtration (each unit)

- Filtrate Total Suspended Solids, TSS
- Filtrate Flow Rate
- Filtrate Flow Duration
- Filtrate Flow Frequency
- Filtrate Flow BOD$_5$
- Filtrate pH
- Cake Quantity
- Cake TSS

10. Centrifuge

- Centrate Total Suspended Solids, TSS
- Centrate Flow Rate
- Centrate Frequency
- Centrate Duration
- Centrate BOD$_5$
- Centrate pH
- Cake Quantity
- Cake TSS

11. Belt Filters

- Filtrate Total Suspended Solids, TSS
- Filtrate Flow Rate
- Filtrate Flow Duration
- Filtrate Flow Frequency
- Filtrate Flow BOD$_5$
- Filtrate pH
- Cake Quantity
- Cake TSS

12. Sand Beds

- Filtrate Total Suspended Solids, TSS
- Filtrate Flow Rate and Duration (if measurable)
- Filtrate Flow Frequency
- Filtrate Flow BOD$_5$
- Cake Quantity
- Cake TSS

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TABLE 3. (continued)

13. Sludge Lagoons

- Supernatant Total Suspended Solids, TSS
- Supernatant Flow Rate
- Supernatant Flow Frequency
- Supernatant Flow Duration
- Supernatant BOD_5
- Sludge Settleability
- Cake Quantity
- Cake TSS

14. Heat Treatment/Wet Air Oxidation

- Supernatant Total Suspended Solids, TSS
- Supernatant Flow Rate
- Supernatant Frequency
- Supernatant Duration
- Supernatant BOD_5
- Underflow Sludge Pumping Rate
- Underflow Sludge Pumping Frequency
- Underflow Sludge Pumping Duration
- Underflow TSS

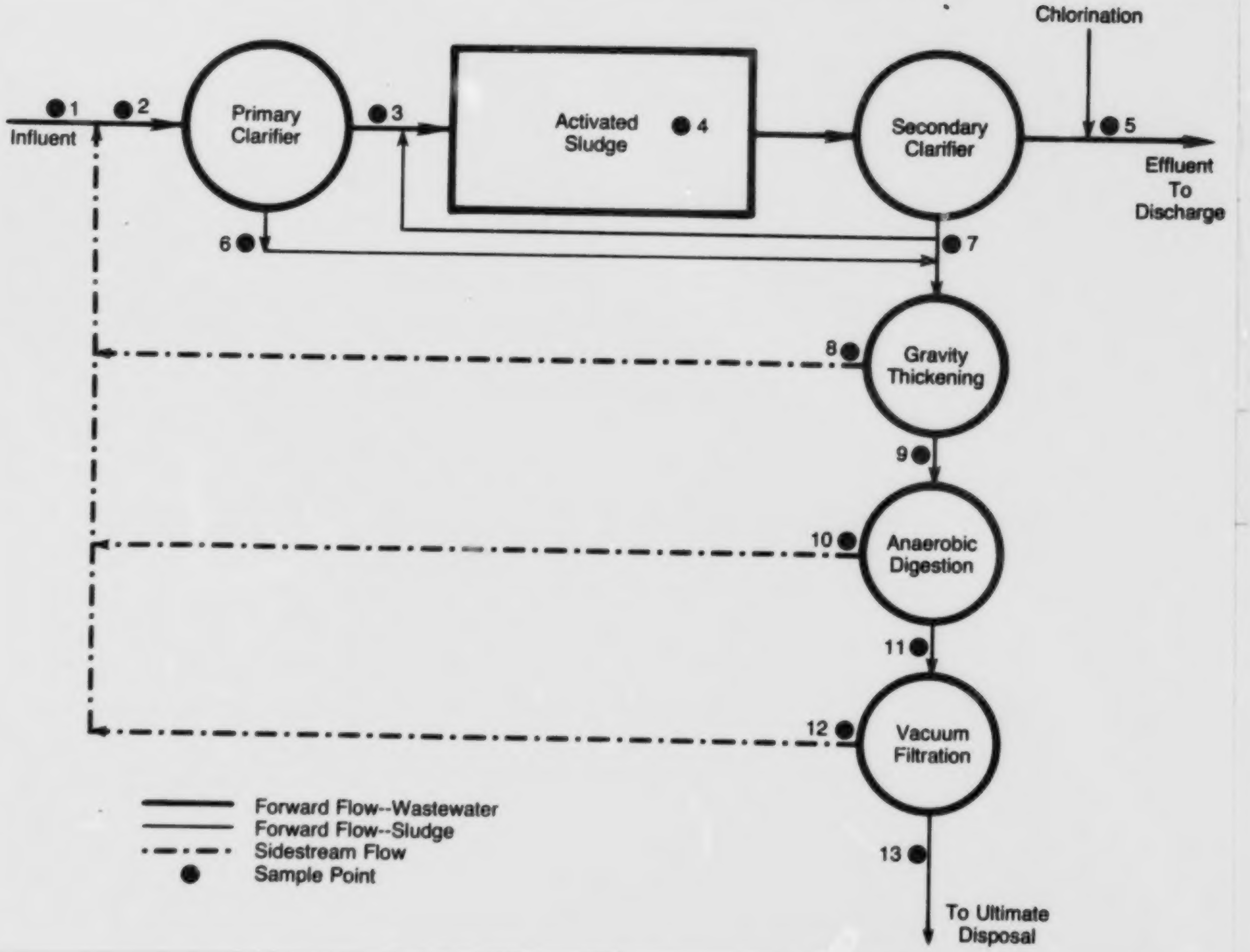
Influent
1
2
Primary Clarifier
3
Activated Sludge
4
Secondary Clarifier
Chlorination
5
Effluent To Discharge
6
7
8
Gravity Thickening
9
10
Anaerobic Digestion
11
12
Vacuum Filtration
13
To Ultimate Disposal
Forward Flow--Wastewater
Forward Flow--Sludge
Sidestream Flow
Sample Point

Figure 1. Example process monitoring program.

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General Description--

Three mainstream treatment process Evaluation Algorithms have been developed (P, AS, and TF/RBC). These algorithms are located in Section 3. Following are descriptions of the methodology to be utilized with the Evaluation Algorithms.

The first step in the evaluation and control of sidestream impact is to determine if a sidestream is indeed responsible for an observed loss in performance in a mainstream process (such as primary sedimentation or secondary activated sludge processes). In order to make this determination, the user must select the appropriate Evaluation Algorithm(s) and complete the indicated evaluations before any other activity is initiated.

Theoretically, once an Evaluation Algorithm is begun it is a self perpetuating exercise that cannot be terminated until all operational controls and design modifications that are applicable to the POTW are implemented, or the impacts have been reduced to an acceptable level. While this is true, the user is advised to go to other algorithms and matrices before returning to the original algorithm for further evaluation. Although the process appears to be continuous it is temporarily placed on hold at times so that another Evaluation Algorithm can be started and the two kept on the same level of progress.

In brief, the user evaluates the mainstream processes to determine if a sidestream impact exists and, if so, implements operational changes at the mainstream and at the source of the sidestream to control or reduce the impact. In order to determine if the changes have been partially or fully successful in controlling the impact, the processes must then be reevaluated by using the original Evaluation Algorithms again. This time, however, if a problem still exists (and knowing that operational methods have been tried to correct the condition), the user is referenced to design modifications to control the impact.

As an example, consider a POTW with the mainstream treatment processes consisting of primary clarification and activated sludge. The user begins by using the Evaluation Algorithm for primary clarification and follows it through, answering all questions and making the necessary decisions until one evaluation cycle is completed. As the user proceeds through the algorithm, any addresses the user is referred to are noted on the Evaluation Algorithm Checklist (see Table 4). At the end of one evaluation cycle this algorithm is put on temporary hold and the Evaluation Algorithm for activated sludge is begun. The same procedure is used until one evaluation cycle of this algorithm is completed and all referenced addresses are noted on the Evaluation Algorithm Checklist. This completes the first evaluation

TABLE 4. EVALUATION ALGORITHM CHECKLIST

	1		2		3		4	
	Control	Required	Section Number	Page Number	Is Design Modification Required		Section Number	Page Number
Primary Clarification								
Solids Impact		1	4	54		1	6	103
Hydraulic Impact		1	4	54		2	6	103
Dissolved Oxygen		1	4	54		3	6	103
Activated Sludge								
Hydraulic Impact		10	4	56		10	6	104
pH Impact						11	6	104
Solids Impact		19	4	59		12	6	104
BOD_5 Impact		25	4	60		13	6	104
Trickling Filter								
Hydraulic Impact		40	4	63		20	6	105
pH Impact						21	6	105
Solids Impact		43	4	63		22	6	105
BOD_5 Impact		43	4	63		23	6	105
RBC								
Hydraulic Impact		62	4	65		30	6	105
pH Impact						31	6	105
Solids Impact		60	4	65		32	6	105
BOD_5 Impact		60	4	65		33	6	105

cycle of the Evaluation Algorithms and both are placed on temporary hold.

The user now uses the Evaluation Algorithm Checklist to recall the proper address and enters the appropriate Mainstream Operational Control Algorithms. These algorithms contain operational modifications to be made at mainstream treatment processes. The user proceeds through the Operational Control Algorithm answering all questions and making the necessary decisions until one evaluation cycle is completed. As the user proceeds through the algorithm, any reference addresses are noted on the Operational Control Algorithm Checklist (see Table 5). This process is repeated until one evaluation cycle is completed for all mainstream treatment processes addressed on the Evaluation Algorithm Checklist. The Operational Control Algorithms are then placed on temporary hold.

At the end of each Mainstream Operational Control Algorithm the user is sent to the Sidestream Operational Control Algorithms which correspond to his system. These algorithms contain operational modifications to be made at sidestream generators.

A procedure similar to that applied previously is used, where the user proceeds through all algorithms answering all questions and making the necessary decisions until one evaluation cycle is completed. As the user proceeds through the algorithms, any referenced addresses are noted on the Operational Control Algorithm Checklist.

When the user has completed this task he has finished the first cycle for all algorithms. The Operational Control Algorithm Checklist is now reviewed and the operational modifications are ranked for implementation, the criteria being specific to each POTW. Once operational modifications are implemented, the POTW is reevaluated following the same procedure -- in other words, a second cycle.

This continues until the impacts are sufficiently controlled or all operational modifications are implemented. If the impacts have not been sufficiently controlled and all of the applicable operational modifications have been implemented, the user is referred to the Design Modifications Matrix in Section 6.

A similar process takes place within the matrix as occurred within the Operational Control Algorithms and Evaluation Algorithms. Design modifications are listed on the design modification checklists in Tables 6 and 7.

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TABLE 5. CONTROL ALGORITHM CHECKLIST

Place a Check ☑ in the Appropriate Box

	Address		Action Statement	Does This Action Apply To The POTW?		Check When Applicable Action Taken
				YES	NO	
Primary Clarification						
	1	◇	Maintain Low Sludge Blanket			
	3 or 5	◇	Reduce Variability in Sludge Removal			
Activated Sludge	14	◇	Dampen Influent Flow Surges			
	15	◇	Dampen Effluent Flow Surges			
	18	◇	Maintain Low Sludge Blanket			
	20	◇	Increase Aeration Output			
	22	◇	Utilize Flocculant Aids			
	26	◇	Increase Aeration Output - See 20			
	29	◇	Increase Recycle Rate During Shock Load			
	30	◇	Adjust Waste Sludge Rate			
	31	◇	Reduce Variability in Sludge Removal			
Trickling Filter	42 or 45	◇	Adjust Recycle to Forward Flow Ratio			
	46	◇	Force Ventilate Filter Bed			
	48	◇	Utilize Flocculant Aids			

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TABLE 5. (continued)

	Address		Action Statement	Does This Action Apply To the POTW? YES	NO	Check When Applicable Action Taken
	49	◇	Reduce Variability in Sludge Removal			
	50	◇	Maintain Low Sludge Blanket			
RBC	61	◇	Increase Rotational Speed			
	63	◇	Dampen Influent Flow Surges			
	65	◇	Utilize Flocculant Aids			
	66	◇	Reduce Variability in Sludge Removal			
	67	◇	Maintain Low Sludge Blanket			
Gravity Thickening	81	◇	Eliminate or Minimize Dilution Water			
	87	◇	Blend Sludges			
	89	◇	Utilize Flocculant Aids			
	90	◇	Reduce Detention Time			
	92	◇	Redirect Flow to Grit Chamber			
	93	◇	Minimize Clarifier Detention Time-See 1, 18, 50, 67			
	94	◇	Reduce Overflow Variability-See 3, 5, 31, 49, or 66			
	94	◇	Reduce Underflow Variability			

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TABLE 5. (continued)

	Address		Action Statement	Does This Action Apply To The POTW? YES	NO	Check When Applicable Action Taken
DAF						
	102	◇	Reduce Variability in Sludge Feed			
	103	◇	Utilize Flocculant Aids			
	104	◇	Clean Packing			
	105	◇	Minimize Cake Inventory			
	106	◇	Minimize Settled Solids			
Anaerobic Digestion	110	◇	Reduce Variability in Sludge Feed-See 94			
	113	◇	Reduce Variability in Sludge Removal			
	114 or 116	◇	Reduce Variability in Supernatant Removal			
	115	◇	Minimize Sludge Inventory			
	117	◇	Redirect Flow to Thickener			
	122	◇	Correct Digester Loading			
	125	◇	Correct Digestion Performance			
Aerobic Digestion	130	◇	Allow Proper Settling Time			
	131	◇	Reduce Variability in Supernatant Removal			

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TABLE 5. (continued)

	Address	Action Statement	Does This Action Apply To The POTW?		Check When Applicable Action Taken
			YES	NO	
	132	◇ Reschedule Supernatant Removal			
	133	◇ Reduce Supernatant Removal Interferences			
Vacuum Filters	140	◇ Schedule Shutdown			
	141	◇ Redirect Tank Drains to Thickeners			
	142	◇ Schedule Cleaning			
	143	◇ Redirect Filtrate to Thickeners			
	145	◇ Neutralize pH			
	147 or 151	◇ Optimize Cleaning			
	148	◇ Clean or Replace Springs			
	149 or 152	◇ Optimize Chemical Conditioning			
	155	◇ Change Filter Cloths			
	156	◇ Stop Overflow			
Centrifuges	160	◇ Schedule Shutdown			
	161	◇ Redirect Tank Drains to Thickeners			
	162	◇ Redirect Centrate to Thickeners			

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TABLE 5. (continued)

	Address		Action Statement	Does This Action Apply To The POTW? YES	 NO	Check When Applicable Action Taken
	165	◇	Neutralize pH			
	166	◇	Optimize Chemical Conditioning			
	168	◇	Reduce Conveyor Speed			
	169	◇	Decrease Feed Rate			
	171	◇	Optimize Feed Duration			
	172	◇	Extend Cycle Time			
	173	◇	Adjust Bowl Speed			
Belt Filters	180	◇	Schedule Shutdown			
	181	◇	Redirect Tank Drains to Thickeners			
	182	◇	Schedule Cleaning			
	183	◇	Redirect Filtrate to Thickeners			
	184	◇	Align Belts			
	186	◇	Neutralize pH			
	187	◇	Optimize Chemical Conditioning			

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TABLE 5. (continued)

	Address	Action Statement	Does This Action Apply To The POTW?		Check When Applicable Action Taken
			YES	NO	
	190 ◇	Change Filter Cloths			
	191 ◇	Stop Overflow			
Sand Beds	200 ◇	Maintain Sand Depth			
	201 ◇	Install/Align Splash Blocks			
Sludge Lagoons	210 ◇	Optimize Settling Time			
	211 ◇	Reduce Variability in Supernatant Removal			
	212 ◇	Reschedule Supernatant Removal			
	213 ◇	Reduce Supernatant Removal Interference			
HT/WAO	220 ◇	Minimize Temperature/Pressure			
	221 ◇	Reduce Solids Retention Time			
	223 ◇	Redirect Flow to Grit Chamber			
	225 ◇	Utilize Flocculant Aids			
	226 ◇	Reduce Variability in Supernatant Removal			

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TABLE 6. MAINSTREAM DESIGN MODIFICATION CHECKLIST

Mainstream Reference Number	Modification Reference Number	Applicable Modification Alternative	Scheduled for Implementation	Implementation Completed
1	1	add conditioning chemicals		
	2	increase clarifier area		
	3	increase weir length		
2	1	increase clarifier area		
	2	install variable speed pump		
3	1	aerate grit chamber		
10	1	add conditioning chemicals		
	2	increase clarifier		
11	1	add pH control		
12	1	add conditioning chemicals		
	2	increase clarifier area		
	3	increase weir length		
13	1	increase aeration		
20 30	1	add filter area		
21 31	1	add pH control		
22 32	1	add conditioning chemicals		
	2	increase clarifier area		
	3	increase weir length		
23	1	increase recycle flow range		
	2	provide mechanical ventilation		
	3	increase specific surface		
	4	add filter area		
33	1	add filter area		
	2	increase rotation speed		
	3	aerate RBC channel		

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TABLE 7. SIDESTREAM DESIGN MODIFICATION CHECKLIST

Sidestream Generator	Modification Reference Number	Applicable Design Modification Alternative	Scheduled for Implementation	Implementation Completed
Gravity Thickener	GT 1-1	add polymer system		
	2	add floculation center well		
	3	add supernatant equalization		
	4	increase SWD		
	GT 2 -1	add dilution water		
	2	equalize and aerate supernatant		
	GT 3 -1	add supernatant equalization		
Dissolved Air Flotation	DAF 1-1	Add polymer system		
	2			
	DAF 3 -1	add supernatant equalization		
Anaerobic Digester	AnD 1-1	add supernatant equalization		
	2	increase supernatant withdrawal points		
	AnD 2 -1	equalize and aerate supernatant		
Aerobic Digester	AeD 1-1	add supernatant equalizer		
	2	increase aeration and mixing		
	3	increase supernatant withdrawal point		
Vacuum Filter	VF 2 -1	add precoat		
	2	add filtrate equalization		
Centrifuge	C 2 -1	add second stage centrifuge		
	2	add centrate equalization		
Belt Filter	BF 2 -1	add filtrate equalization		
Vacuum filter, Centrifuge and Belt Filter	VF, C, BF 3 -1	equalize and aerate filtrate/ centrate		
	Vf, C, BF 4 -1	elutriate sludge		
	2	add pH control		
Lagoon	LA 1-1	add supernatant equalization		
Heat Treatment/Wet Air Oxidation	HT/WAO 1-1,HT/WAO 2-1	minimize operating temp. & pressure		
	-2, -3	equalize decant		
	HT/WAO 2 -2	add polymer system		
	HT/WAO 3 -1	add sidestream aerobic treatment		

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Again, evaluation cycles are repeated until either the impacts are sufficiently mitigated or all of the applicable design modifications are implemented.

Figure 2 presents a graphical summary of the evaluation process.

Results--

Through the use of the Evaluation Algorithms, the user is able to evaluate the POTW performance (both overall and by individual process/operation) and identify problem areas. Also, these algorithms permit the user to interconnect with and use the Operational Control Algorithms and Design Modifications Matrix.

Mainstream Operational Control Algorithms

Purpose--

The purpose of these algorithms is to provide operating modifications that can be applied to mainstream treatment processes to aid in controlling the impact of a sidestream return on overall POTW treatment efficiency.

General Description--

A general description of the use of these algorithms was included previously in the description for the Evaluation Algorithms. Items of note are:

1. The Mainstream Operational Control Algorithms can only be entered through the Evaluation Algorithms.
2. Selection of those operating modifications to be implemented is based on criteria or controlling conditions specific to each POTW.
3. The only method available to exit the Mainstream Operational Control Algorithm is by entering the appropriate Sidestream Operational Control Algorithms.

Results--

Through the use of the Mainstream Operational Control Algorithms, the user has identified operational modifications which should aid in controlling the impacts of sidestream recycle on POTW treatment efficiency. The operational modifications are for mainstream processes only and do nothing to change the characteristics of the sidestreams. These algorithms also permit the user to interconnect with and use the Sidestream Control Algorithms.

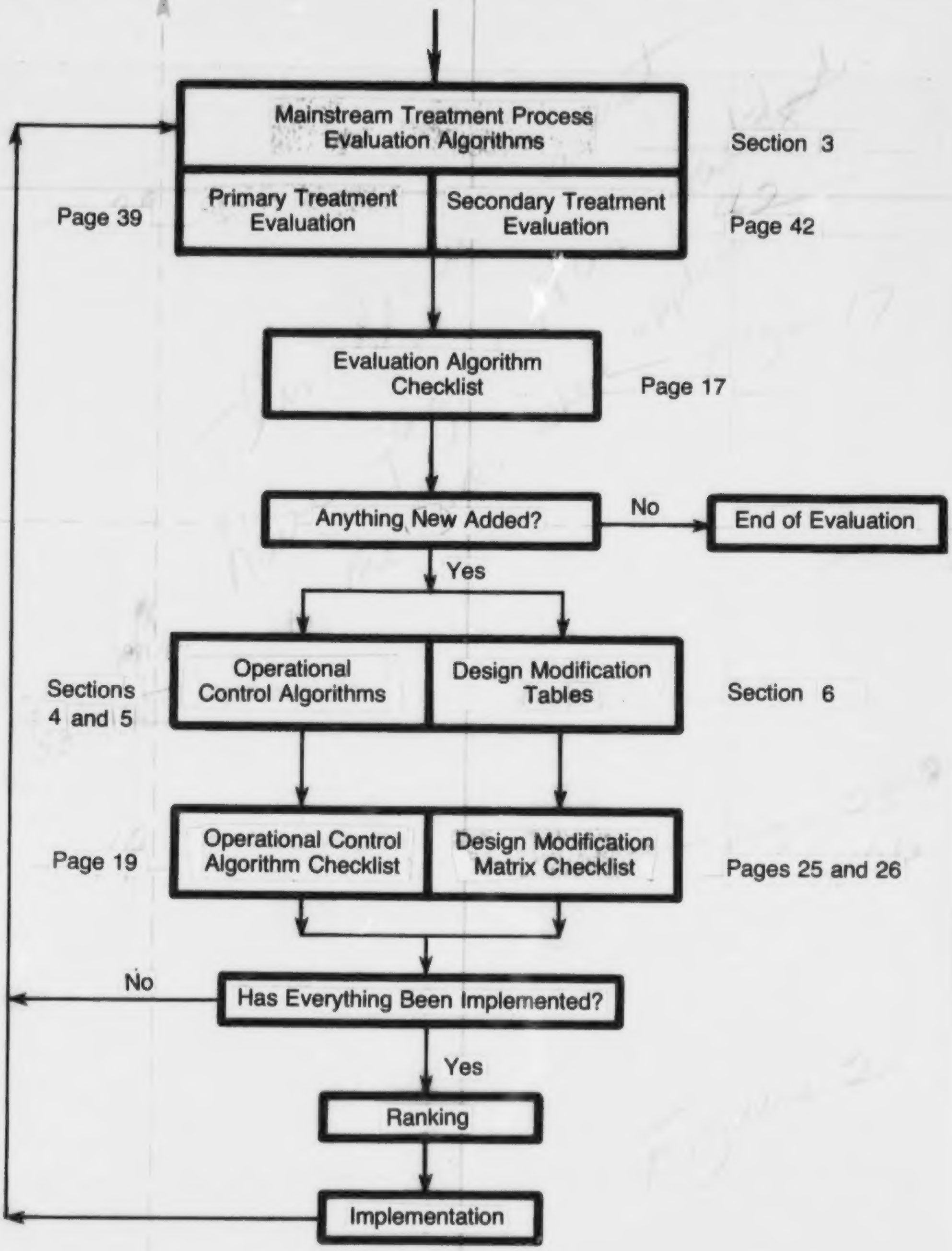
Mainstream Treatment Process Evaluation Algorithms
Section 3
Page 39
Primary Treatment Evaluation
Secondary Treatment Evaluation
Page 42
Evaluation Algorithm Checklist
Page 17
Anything New Added?
No
End of Evaluation
Yes
Sections 4 and 5
Operational Control Algorithms
Design Modification Tables
Section 6
Page 19
Operational Control Algorithm Checklist
Design Modification Matrix Checklist
Pages 25 and 26
No
Has Everything Been Implemented?
Yes
Ranking
Implementation

Figure 2. Summary of the evaluation process.

Sidestream Operational Control Algorithms

Purpose--

The purpose is to provide operating modifications that can be applied to sidestream generators to aid in mitigating the impact of sidestream return on overall POTW treatment efficiency.

General Description--

A general description of the use of these algorithms was included previously in the description for the Evaluation Algorithms. Items of note are:

1. The Sidestream Operational Control Algorithms can only be entered through the Mainstream Operational Control Algorithms.

2. Selection of those operating modifications to be implemented are based on criteria or controlling conditions specific to each POTW.

3. The only method available to exit the Sidestream Operational Control Algorithms is by returning to the Evaluation Algorithms.

Results--

Through the use of Sidestream Operational Control Algorithms, the user has identified operational modifications which should aid in controlling the impacts of sidestream recycle on POTW treatment efficiency. The operational modifications are for application at the sidestream generator and are intended to improve the characteristics of the sidestream generated. They do not recommend any operational modifications to the mainstream treatment process.

Design Modifications to Existing Facilities

Purpose--

The purpose is to provide a listing of design modifications that can be applied to both mainstream processes and sidestream generators. These modifications will aid the user in controlling the impact of sidestream return on overall POTW treatment efficiency.

General Description--

A general description of how the Design Modifications Matrix is used to control the impacts of sidestream recycle on POTW treatment efficiency is contained in the description for the Evaluation Algorithms. A detailed description is contained in Section 6.

Items of note are:

1. The design modifications to existing facilities (matrix and accompanying material) can only be entered through the Evaluation Algorithms.

2. Selection of those modifications to be implemented is based on a cost effectiveness comparison and criteria or controlling conditions specific to the POTW.

3. The only method available to exit the Design Modifications Matrix is by returning to the Evaluation Algorithms.

Design Guidelines

Purpose--

These design guidelines are to be utilized when selecting treatment processes, preparing designs for new facilities, or preparing designs for the upgrading/expansion of existing facilities, to ensure that the impacts of sidestream recycle on POTW treatment efficiency are considered during the selection/design.

General Description--

A summary table (Table 8) has been developed which presents sidestream characteristics. Data on flow, suspended solids, and BOD_5 are presented for each sidestream generator and the typical wastewater treatment process flow scheme in which they might appear. For a further explanation of the methodology used to calculate these parameter values see Appendix A. The characteristics are presented with the following units:

1. Flow - gallons per day (gpd).

2. Total BOD_5 - concentration (mg/L) and loading (lbs/day).

3. Total SS - concentration (mg/L) and loading (lbs/day).

Flow and loadings are based on a forward flow of one million gallons per day (1.0 mgd).

In general, the designer/engineer can enter Table 8 for the sidestream generator of concern and select the appropriate data by using whichever typical wastewater treatment process flow scheme most closely represents his own. Total hydraulic, solids, and BOD_5 loadings for that sidestream generator can be

TABLE 8. SUMMARY OF SIDESTREAM CHARACTERISTICS

Sidestream	Process Description	Flow (gpm)	Loading (Lbs/Day) TBOD	Loading (Lbs/Day) TSS	Concentration (mg/L) TBOD	Concentration (mg/L) TSS
Gravity Thickening	P + AS + GT + AnD + VF	9,240	10.4	23.1	135	300
	P + AS + GT + AnD + SB	9,820	13.7	24.6	167	300
	P + AS + GT + AnD + BC	9,600	13.0	24.0	162	300
	P + AS + GT + AnD + SBSC	9,530	12.9	23.9	161	300
	P + AS + GT + AnD + BF	9,730	13.3	24.3	163	300
	P + TF + GT + AnD + VF	1,220	1.9	3.1	190	300
	P + TF + GT + AnD + SB	1,150	1.8	2.9	190	300
	P + TF + GT + AnD + BC	1,160	1.8	2.9	191	300
	P + TF + GT + AnD + SBSC	1,140	1.9	2.9	191	300
	P + TF + GT + AnD + BF	1,230	1.9	3.1	187	300
	P + RBC + GT + AnD + VF	1,390	2.1	3.5	184	300
	P + RBC + GT + AnD + SB	1,340	2.1	3.4	188	300
	P + RBC + GT + AnD + BC	1,360	2.1	3.4	188	300
	P + RBC + GT + AnD + SBSC	1,380	2.2	3.4	189	300
	P + RBC + GT + AnD + BF	1,360	2.1	3.4	189	300
Dissolved Air Flotation	P + AS + DAF + AnD + VF	10,100	11.1	21.0	133	250
	P + AS + DAF + ACD + VF	10,000	11.4	21.0	136	250
	P + AS + DAF + AnD + SB	10,000	11.5	20.9	137	250
	P + AS + DAF + ACD + SB	10,000	11.5	20.9	138	250
	P + AS + DAF + AnD + BC	10,000	11.3	20.9	135	250
	P + AS + DAF + AnD + SBSC	10,500	8.7	21.9	100	250
	P + AS + DAF + AnD + BC	10,000	11.5	20.9	137	250
	P + AS + DAF + AnD + SBSC	10,600	12.1	22.0	137	250
	P + AS + DAF + AnD + BF	10,100	11.5	21.1	136	250
	P + AS + DAF + AnD + BF	10,200	11.6	21.2	13[illegible]	250
	P + TF + DAF + AnD + VF	822	0.6	1.4	82.2	200
	P + TF + DAF + AnD + SB	777	0.5	1.3	84.1	200
	P + TF + DAF + AnD + BC	786	0.6	1.3	84.0	200
	P + TF + DAF + AnD + SBSC	819	0.6	1.4	81.2	200
	P + TF + DAF + AnD + BF	804	0.6	1.3	83.1	200
	P + RBC + DAF + AnD + VF	1,220	0.9	2.0	92.5	200
	P + RBC + DAF + AnD + SB	1,160	0.9	1.9	94.2	200
	P + RBC + DAF + AnD + BC	1,170	0.9	2.0	94.2	200
	P + RBC + DAF + AnD + SBSC	2,000	0.9	2.0	94.2	200
	P + RBC + DAF + AnD + BF	1,180	0.9	2.0	93.0	200
Anaerobic Digestion	P + AnD + VF	908	5.5	22.7	731	3,000
	P + AS + GT + AnD + VF	2,610	15.1	80.4	694	3,700
	P + AS + GT + AnD + SB	1,940	14.2	60.0	879	3,700
	P + AS + DAF + AnD + SB	1,760	12.9	54.3	881	3,700

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TABLE 8. (continued)

Sidestream	Process Description	Flow (gpm)	Loading (Lbs/Day) TBOD	Loading (Lbs/Day) TSS	Concentration (mg/L) TBOD	Concentration (mg/L) TSS
Anaerobic Digestion (Continued)	P + AS + GT + AnD + BC	1,960	13.8	60.4	844	3,700
	P + AS + GT + AnD + SBSC	2,060	14.0	63.5	815	3,700
	P + AS + DAF + AnD + BC	1,640	11.5	50.7	840	3,700
	P + AS + DAF + AnD + SBSC	2,300	11.8	71.1	615	3,700
	P + AS + GT + AnD + BF	2,010	14.3	61.9	854	3,700
	P + AS + DAF + AnD + BF	1,840	12.9	56.6	842	3,700
	P + TF + GT + AnD + VF	1,030	7.1	33.4	833	3,900
	P + TF + DAF + AnD + VF	1,210	8.1	39.4	805	3,900
	P + TF + GT + AnD + SB	1,010	7.0	33.0	827	3,900
	P + TF + DAF + AnD + SB	1,170	8.1	38.1	826	3,900
	P + TF + GT + AnD + BC	1,020	6.8	33.1	805	3,900
	P + TF + GT + AnD + SBSC	1,090	7.6	35.4	838	3,900
	P + TF + GT + AnD + BC	1,180	8.1	38.2	821	3,900
	P + TF + GT + AnD + SBSC	1,210	8.3	39.4	816	3,900
	P + TF + GT + AnD + BF	1,030	7.0	33.6	816	3,900
	P + TF + DAF + AnD + BF	1,200	8.1	39.0	812	3,900
	P + RBC + GT + AnD + VF	1,160	8.0	37.7	826	3,900
	P + RBC + DAF + AnD + VF	1,240	8.5	40.2	824	3,900
	P + RBC + GT + AnD + SB	1,120	7.9	36.4	847	3,900
	P + RBC + DAF + AnD + SB	1,190	8.4	38.6	852	3,900
	P + RBC + GT + AnD + BC	1,130	8.0	36.6	847	3,900
	P + RBC + GT + AnD + SBSC	1,160	8.1	37.6	839	3,900
	P + RBC + DAF + AnD + BC	1,200	8.4	39.0	844	3,900
	P + RBC + DAF + AnD + SBSC	1,230	8.6	40.1	838	3,900
	P + RBC + GT + AnD + BF	1,140	8.0	37.0	845	3,900
	P + RBC + DAF + AnD + BF	1,210	8.5	39.5	844	3,900
Aerobic Digestion	P + AS + DAF + AeD + VF	852	8.1	35.5	1,130	5,000
	P + AS + DAF + AeD + SB	818	6.8	34.1	1,000	5,000
	P + AS + DAF + AeD + BC	822	6.8	34.3	998	5,000
	P + AS + DAF + AeD + SBSC	597	5.0	24.5	997	5,000
	P + AS + DAF + AeD + BF	838	6.9	34.9	988	5,000

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TABLE 8. (continued)

Sidestream	Process Description	Flow (gpm)	Loading (Lbs/Day) TBOD	Loading (Lbs/Day) TSS	Concentration (mg/L) TBOD	Concentration (mg/L) TSS
Vacuum Filtration	P + AnD + VF	3,471	7.4	37.9	254	1,310
	P + AS + GT + AnD + VF	5,210	16.9	114	389	2,620
	P + AS + DAF + AnD + VF	4,400	14.9	86.7	406	2,360
	P + AS + DAF + AeD + VF	5,190	34.4	95.7	794	2,210
	P + TF + GT + AnD + VF	3,480	9.1	56.0	314	1,930
	P + TF + DAF + AnD + VF	3,750	10.6	64.9	339	2,080
	P + RBC + GT + AnD + VF	3,660	10.3	62.1	337	2,030
	P + RBC + DAF + AnD + VF	3,780	11.1	66.1	351	2,100
Solid Bowl Scroll Centrifuge	P + SBSC	1,660	46.0	90.1	3,320	6,500
	P + AS + GT + AnD + SBSC	2,500	26.0	146	1,250	7,000
	P + AS + DAF + AnD + SBSC	2,350	17.0	137	867	7,000
	P + AS + DAF + AeD + SBSC	611	6.4	15.3	1,250	3,000
	P + TF + GT + AnD + SBSC	1,210	11.8	65.4	1,170	6,500
	P + TF + DAF + AnD + SBSC	1,410	13.3	76.2	1,140	6,500
	P + RBC + GT + AnD + SBSC	1,320	13.0	71.6	1,180	6,500
	P + RBC + DAF + AnD + SBSC	1,440	14.1	77.9	1,180	6,500
Basket Centrifuge	P + BC	184	3.9	7.7	2,570	5,000
	P + AS + GT + AnD + BC	1,720	8.2	25.1	575	1,750
	P + AS + DAF + AnD + BC	1,220	5.8	17.8	570	1,750
	P + AS + DAF + AeD + BC	2,050	6.9	15.4	401	900
	P + TF + GT + AnD + BC	658	3.0	9.3	550	1,700
	P + TF + DAF + AnD + BC	899	4.1	12.7	546	1,700
	P + RBC + GT + AnD + BC	823	3.8	11.7	557	1,700
	P + RBC + DAF + AnD + BC	934	4.3	13.2	556	1,700
Belt Filter	P + AnD + BF	5,710	5.9	20.7	124	434
	P + AS + GT + AnD + BF	13,100	17.6	78.9	161	724
	P + AS + DAF + AnD + BF	11,900	15.6	71.4	158	719
	P + AS + DAF + AeD + BF	15,400	40.1	101.5	312	789
	P + TF + GT + AnD + BF	6,630	7.5	33.6	136	608
	P + TF + DAF + AnD + BF	7,750	9.0	40.0	139	618
	P + RBC + GT + AnD + BF	7,050	8.6	36.2	146	616
	P + RBC + DAF + AnD + BF	7,510	9.3	38.9	147	620

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TABLE 8. (continued)

Sidestream	Process Description	Flow (gpm)	Loading (lbs/Day) TBOD	Loading (lbs/Day) TSS	Concentration (mg/L) TBOD	Concentration (mg/L) TSS
Sand Bed	P + AnD + SB	863	2.6	1.1	357	150
	P + AS + GT + AnD + SB	1,890	5.7	2.8	359	180
	P + AS + DAF + AnD + SB	1,620	4.8	2.4	359	180
	P + AS + DAF + AcD + SB	2,160	2.0	2.7	109	150
	P + TF + GT + AnD + SB	724	2.1	1.1	356	180
	P + TF + DAF + AnD + SB	961	2.9	1.4	356	180
	P + RBC + GT + AnD + SB	880	2.6	1.3	359	180
	P + RBC + DAF + AnD + SB	972	2.9	1.5	357	180
Lagoon	P + AS + LA	1,640	6.6	4.9	480	360
	P + TF + LA	923	3.7	2.8	480	360
	P + RBC + LA	932	3.7	2.8	480	360
Heat Treatment	P + HT	1,670	90.4	34.8	6,500	2,500
	P + AS + HT	14,300	775	358	6,500	3,000
	P + TF + HT	3,050	165	68.8	6,500	2,700
	P + RBC + HT	3,510	190	79.0	6,500	2,700
Wet Air Oxidation	P + WAD	1,870	117	39.1	7,500	2,500
	P + AS + WAD	14,700	918	367	7,500	3,000
	P + TF + WAD	3,570	224	80.5	7,500	2,700
	P + RBC + WAD	3,910	244	88.0	7,500	2,700
Filter Press	P + AnD + FP	1,320	3.6	4.5	331	404
	P + AS + GT + AnD + FP	2,540	7.4	8.2	349	388
	P + AS + DAF + AnD + FP	2,280	6.6	7.7	349	404
	P + AS · DAF + AeD + FP	2,950	2.4	3.8	97.6	154
	P + TF + GT + AnD + FP	1,380	3.7	4.6	326	398
	P + TF + DAF + AnD + FP	1,600	4.4	4.8	328	359
	P + RBC + GT + AnD + FP	1,520	4.2	4.7	335	371
	P + RBC + DAF + AnD + FP	1,630	4.5	4.8	333	356
Purifax	P + PX	1,890	3.2	1.6	200	100
	P + AS + PX	12,300	20.5	10.3	200	100
	P + TF + PX	3,100	5.2	2.6	200	100
	P + RBC + PX	3,520	5.9	2.9	200	100

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calculated by multiplying by the design forward flow. Total loadings for the sidestreams recycled back to the POTW can be obtained by summing those loadings for the individual sidestream generators. This total loading can then be added to the expected influent loadings and the processes/operations properly sized.

It is predicted that the sidestream loadings (with the possible exception of HT/WAO) do not cause adverse impacts on POTW treatment efficiency; but, rather that the manner in which they are returned causes the adverse impacts. This document, therefore, recommends that all sidestreams be returned to an equalization tank/basin with 24-hour detention time from which they are metered back to the head of the POTW. The rate would be dependent on controlling conditions at the plant, but would either be continuous or during low loading periods.

Results--

By using Table 8 and the methodology presented in Section 6, the user can predict the increase in loadings to a POTW caused by the recycle of sidestreams. The processes/operations can then be designed accordingly. Also, methods have been developed to aid the engineer in recycling the sidestreams in the best manner possible.

Checklists

Purpose--

These checklists provide the user with an organizational tool as he works through the algorithms and modifications. They are important since they provide the only means by which the user can keep track of the status and progress of any project to characterize and control the impacts of sidestream recycle on POTW's.

General Description--

Blank checklists are included as Tables 4, 5, 6, and 7. Methodology of their use has been presented previously in this section.

Results--

The checklists aid the user in organizing the required programs and selecting modifications, as well as serving as a running record for the project.

PROCESS MONITORING REQUIREMENTS

General

In order to use the evaluation, control, and design tools presented in Sections 3 through 6, a process monitoring program must be initiated. The more detailed and comprehensive this program, the better the quality of the data and the easier it will be to use the tools presented in this document. It also leads to increased accuracy in predicting the results of implementing the operational or design modifications and, consequently, to better POTW performance.

Since this document is written in such a manner as to be applicable to as many POTW's as possible, it is impossible to describe detailed monitoring programs for all potential wastewater treatment process flow schemes. Those parameters which need to be monitored are summarized by mainstream process and sidestream generator and presented in Table 3. Many of these parameters may be part of some existing monitoring program.

Example Process Monitoring Program

The material following represents an ideal process monitoring program. It is realized that some of the parameters listed may already be monitored at many POTW's, while at other POTW's manpower, space, or equipment limitations may necessitate implementation of a simpler monitoring program. The program should be flexible and tailored to meet the needs of the user. The longer the monitoring program, the more samples taken, and the more analyses made will increase the accuracy of the results and diagnoses. The recommended modifications will also have more impact in improving overall POTW treatment efficiency.

The example process monitoring program is designed for the wastewater treatment process flow scheme depicted in Figure 1. Sampling points are located by reviewing the parameters listed under each element in Table 3. For this flow scheme, 13 sampling points are required.

A two-phase monitoring program is best and optimizes the results. The first phase may require a change in operating procedures, while the second phase does not.

The first phase requires that sidestreams not be recycled to the treatment processes for at least one shift (eight hours), preferably during peak loading conditions, so the true POTW treatment efficiency can be determined. The recommended frequency of sampling is once every three days for a 30-day period. Sampling is to occur over the last four hours of the eight-hour shift and should be hourly grab. The sample points used during this phase are 1, 3, 4, 5, 6, and 7 (see Figure 1).

The second phase requires normal operation of the POTW. Sampling of mainstream treatment processes should be continuous (or hourly grab) over a 24-hour period, while sidestream data should be obtained whenever the sidestream generator is in operation. Continuous sampling should occur at points 1, 2, 3, 4, 5, 6, and 7, with intermittent sampling at points 8, 9, 10, 11, 12, and 13, during operation.

The sidestream and sludge sampling (points 8 through 13) should include a minimum of three samples during each period of operation. It is recommended that the second phase of sampling run for 10 consecutive days.

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SECTION 3

EVALUATION ALGORITHMS

GENERAL

This section presents three algorithms that can be used to evaluate mainstream treatment processes primarily with respect to the impact of sidestreams. The mainstream processes that were considered include:

1. Primary clarification (PC).
2. Activated sludge secondary treatment (AS).
3. Trickling filter/rotating biological contactor secondary treatment (TF/RBC).

Secondary clarification was considered as part of each secondary treatment process as indicated in Figure 3 below:

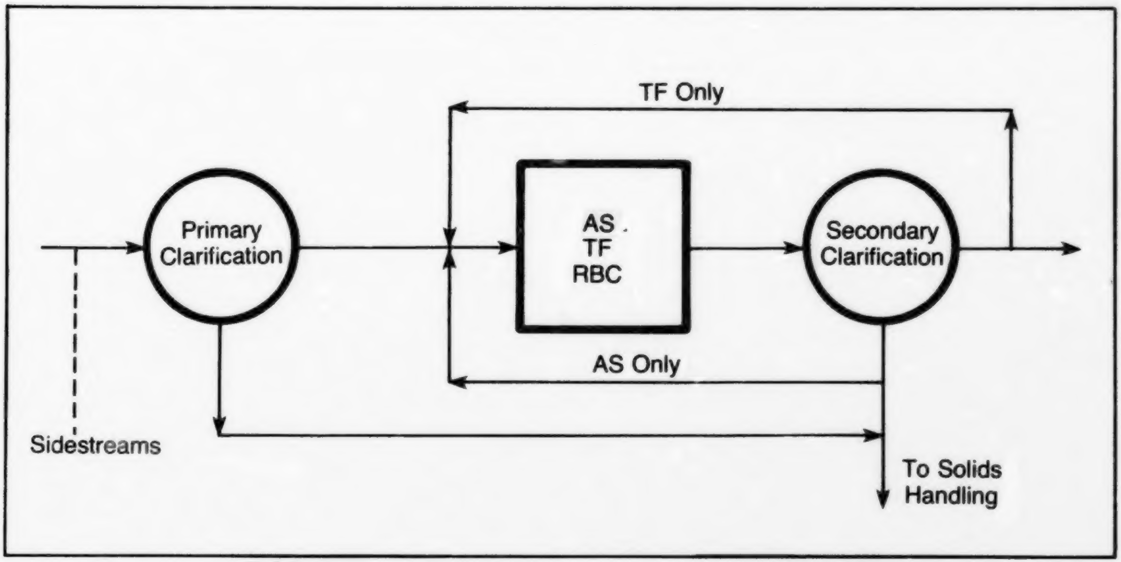
TF Only
Primary Clarification
AS
TF
RBC
Secondary Clarification
AS Only
Sidestreams
To Solids Handling

Figure 3. Secondary treatment process.

Each mainstream algorithm was developed to allow the user to apply the information obtained through a monitoring program (see Section 2) to identify problem areas and possible corrective operating controls and/or design modifications.

PURPOSE

The purpose of the algorithms presented in this section is to provide guidance methodologies for determining the impact of sidestreams on mainstream processes.

ALGORITHMS

Each algorithm presented is followed by a brief discussion of the potential sidestream impacts, the actual presence of which can be determined through the use of the algorithm.

Primary Clarification Evaluation of Sidestream Impact

Information contained in this section includes:

- Primary Clarification Evaluation Algorithm
- Discussion

The use of this algorithm is described in the User's Guide in Section 2 and an example is provided in Appendix B. Before the use of this algorithm, the user must develop and implement a Process Monitoring Program specific to the facility as is described in Section 2. The following algorithm is designed to apply to a large number of POTW's; therefore, it must be tailored to fit the user's requirements for the specific POTW.

The primary clarification evaluation algorithm is presented in Figure 4.

Sidestream Impacts on Primary Clarification--

The purpose of the primary clarifier is to remove (by gravity settling) suspended solids that are contained in the influent wastewater. Sidestream impacts are identified that have the potential of decreasing the performance of the clarifier and resulting in primary effluent suspended solids concentrations equal to or greater than 100 mg/L.

Although the following impacts differ, their effect on the primary clarifier are similar, i.e., all may result in an increase in primary effluent suspended solids concentration.

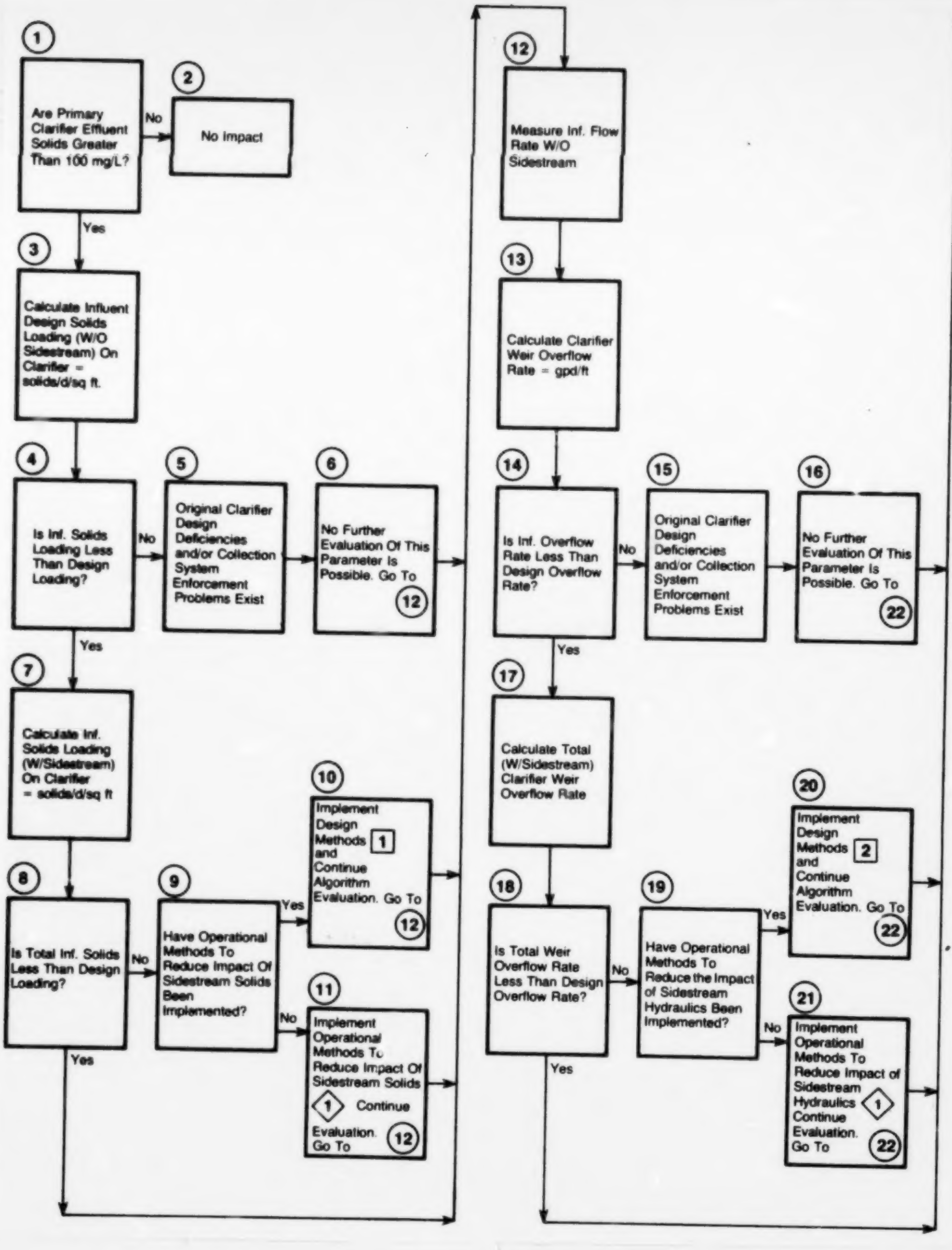
1
Are Primary Clarifier Effluent Solids Greater Than 100 mg/L?
No
2
No Impact
Yes
3
Calculate Influent Design Solids Loading (W/O Sidestream) On Clarifier = solids/d/sq ft.
4
Is Inf. Solids Loading Less Than Design Loading?
No
5
Original Clarifier Design Deficiencies and/or Collection System Enforcement Problems Exist
6
No Further Evaluation Of This Parameter Is Possible. Go To 12
Yes
7
Calculate Inf. Solids Loading (W/Sidestream) On Clarifier = solids/d/sq ft
8
Is Total Inf. Solids Less Than Design Loading?
No
9
Have Operational Methods To Reduce Impact Of Sidestream Solids Been Implemented?
Yes
10
Implement Design Methods 1 and Continue Algorithm Evaluation. Go To 12
No
11
Implement Operational Methods To Reduce Impact Of Sidestream Solids 1 Continue Evaluation. Go To 12
Yes
12
Measure Inf. Flow Rate W/O Sidestream
13
Calculate Clarifier Weir Overflow Rate = gpd/ft
14
Is Inf. Overflow Rate Less Than Design Overflow Rate?
No
15
Original Clarifier Design Deficiencies and/or Collection System Enforcement Problems Exist
16
No Further Evaluation Of This Parameter Is Possible. Go To 22
Yes
17
Calculate Total (W/Sidestream) Clarifier Weir Overflow Rate
18
Is Total Weir Overflow Rate Less Than Design Overflow Rate?
No
19
Have Operational Methods To Reduce the Impact of Sidestream Hydraulics Been Implemented?
Yes
20
Implement Design Methods 2 and Continue Algorithm Evaluation. Go To 22
No
21
Implement Operational Methods To Reduce Impact of Sidestream Hydraulics 1 Continue Evaluation. Go To 22
Yes
22

Figure 4. Evaluation of the sidestream impact on primary clarification.

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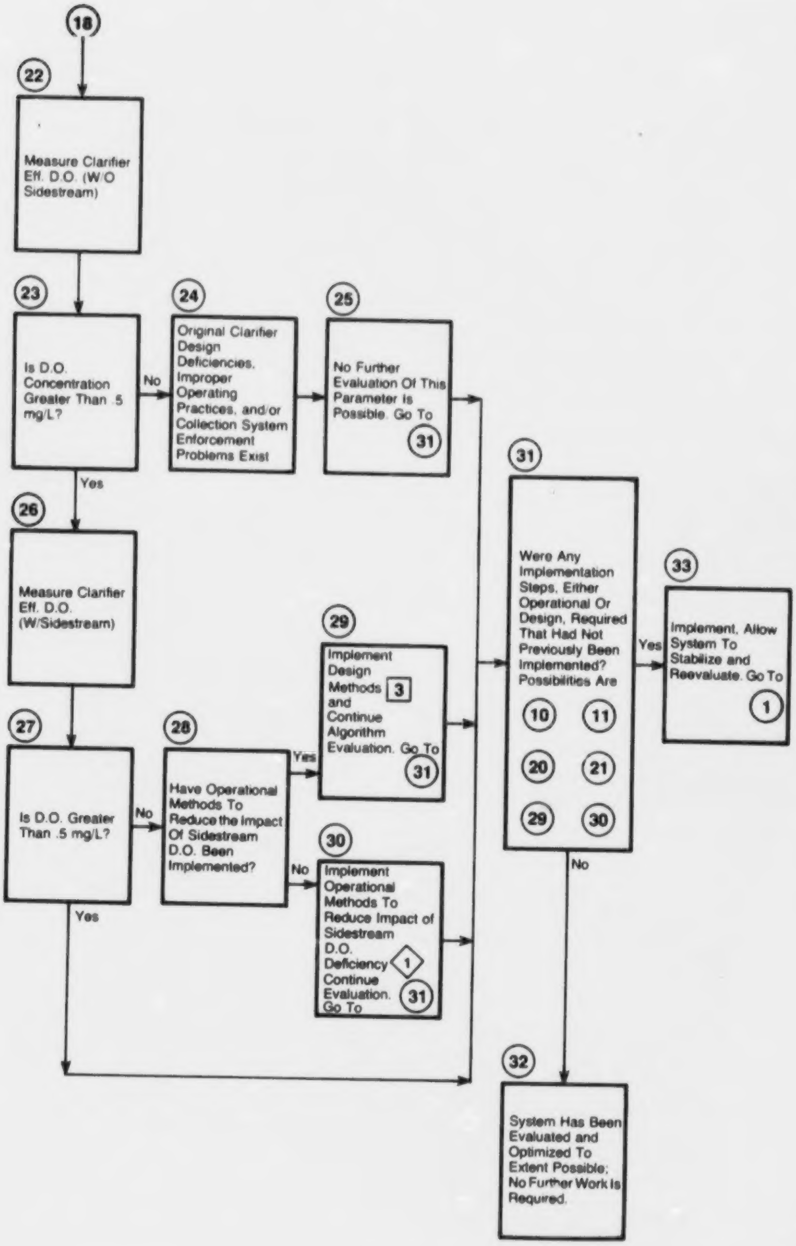
18
22
Measure Clarifier Eff. D.O. (W/O Sidestream)
23
Is D.O. Concentration Greater Than .5 mg/L?
No
24
Original Clarifier Design Deficiencies, Improper Operating Practices, and/or Collection System Enforcement Problems Exist
25
No Further Evaluation Of This Parameter Is Possible. Go To 31
Yes
26
Measure Clarifier Eff. D.O. (W/Sidestream)
27
Is D.O. Greater Than .5 mg/L?
No
28
Have Operational Methods To Reduce the Impact Of Sidestream D.O. Been Implemented?
Yes
29
Implement Design Methods 3 and Continue Algorithm Evaluation. Go To 31
No
30
Implement Operational Methods To Reduce Impact of Sidestream D.O. Deficiency 1 Continue Evaluation. Go To 31
Yes
31
Were Any Implementation Steps, Either Operational Or Design, Required That Had Not Previously Been Implemented? Possibilities Are
10
11
20
21
29
30
Yes
33
Implement, Allow System To Stabilize and Reevaluate. Go To 1
No
32
System Has Been Evaluated and Optimized To Extent Possible; No Further Work Is Required.

Figure 4. (continued)

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Flow (Hydraulic Loading)--

Any hydraulic loading applied to the primary clarifier in excess of the design hydraulic loading, may have the result of "washing out" solids from the clarifier.

To evaluate the sidestream impact, the hydraulic loading with and without the addition of the sidestream must be determined. Once determined, the results are compared to the design hydraulic loading to determine if the actual hydraulic loading (with or without the sidestream) could be responsible for the high (greater than 100 mg/L) suspended solids concentration in the primary clarifier effluent.

If, as a result of the comparison stated above, the actual hydraulic loading of the influent without the sidestream is less than the design hydraulic loading and the actual hydraulic loading of the influent with the sidestream is greater than the design hydraulic loading, then the sidestream is considered to have an impact and appropriate measures are required to reduce the impact.

Solids Loading--

Any solids loading applied to the primary clarifier, in excess of the design solids loading, may result in carry-over of solids from the clarifier.

The evaluation of sidestreams impact on the clarifier for solids loading is accomplished in the same manner as the hydraulic loading evaluation discussed above.

Dissolved Oxygen Concentration--

A low (0.5 mg/L) dissolved oxygen concentration in the clarifier effluent is an indicator of approaching septic conditions which may result in rising sludge which will carry over into the clarifier effluent, causing an increase in suspended solids levels. In order to evaluate this impact, DO measurements are taken of the clarifier effluent with and without addition of the sidestream to the treatment process. If, as a result of the measurement and comparison of the DO readings, the sidestream depresses the primary effluent DO to a level equal to or less than 0.5 mg/L, recommended operational and/or design methods to reduce the impact should be implemented.

Activated Sludge Evaluation of Sidestream Impact

Information contained in this section includes:

- Activated Sludge Evaluation Algorithm
- Discussion

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The use of this algorithm is described in the User's Guide in Section 2 and an example is provided in Appendix B. Before the use of this algorithm, the user must develop and implement a Process Monitoring Program specific to the facility as is described in Section 2. The following algorithm is designed to apply to a large number of POTW's; therefore, it must be tailored to fit the user's requirements for the specific POTW.

The activated sludge algorithm is presented in Figure 5.

The following impacts may all result in an increase in the secondary effluent BOD_5 and/or suspended solids concentrations.

Flow (Hydraulic Loading)--

Hydraulic loading in excess of the design loading applied to the activated sludge secondary treatment process will decrease the hydraulic detention time through the aeration basin and the secondary clarifiers.

The hydraulic loading to the secondary system is determined with and without the addition of the sidestream flow. This is done to rule out an overload condition that may be due to conditions not related to the sidestream.

pH--

The pH in the activated sludge process should be maintained between 6.5 and 8.5.

When sludge conditioning chemicals are used a potential exists for the generation of a sidestream with a low or high pH.

As with the hydraulic loading evaluation, the pH of the mainstream is determined with and without the addition of the sidestream. This is done to rule out an abnormal pH condition that may be due to conditions not related to the sidestream.

Dissolved Oxygen--

The activated sludge process normally requires a minimum dissolved oxygen concentration of 2.0 mg/L. Sidestreams that contain high BOD_5 and suspended solids concentrations may affect the dissolved oxygen level.

The dissolved oxygen concentration in the aeration basin is monitored with and without addition of the sidestream to the process. The sidestream impact on the aeration basin dissolved oxygen concentration is used to evaluate whether sidestream BOD_5 loading and suspended solids loading needs to be determined. It is assumed that sidestream BOD_5 and suspended solids concentrations have no substantial impact on the activated

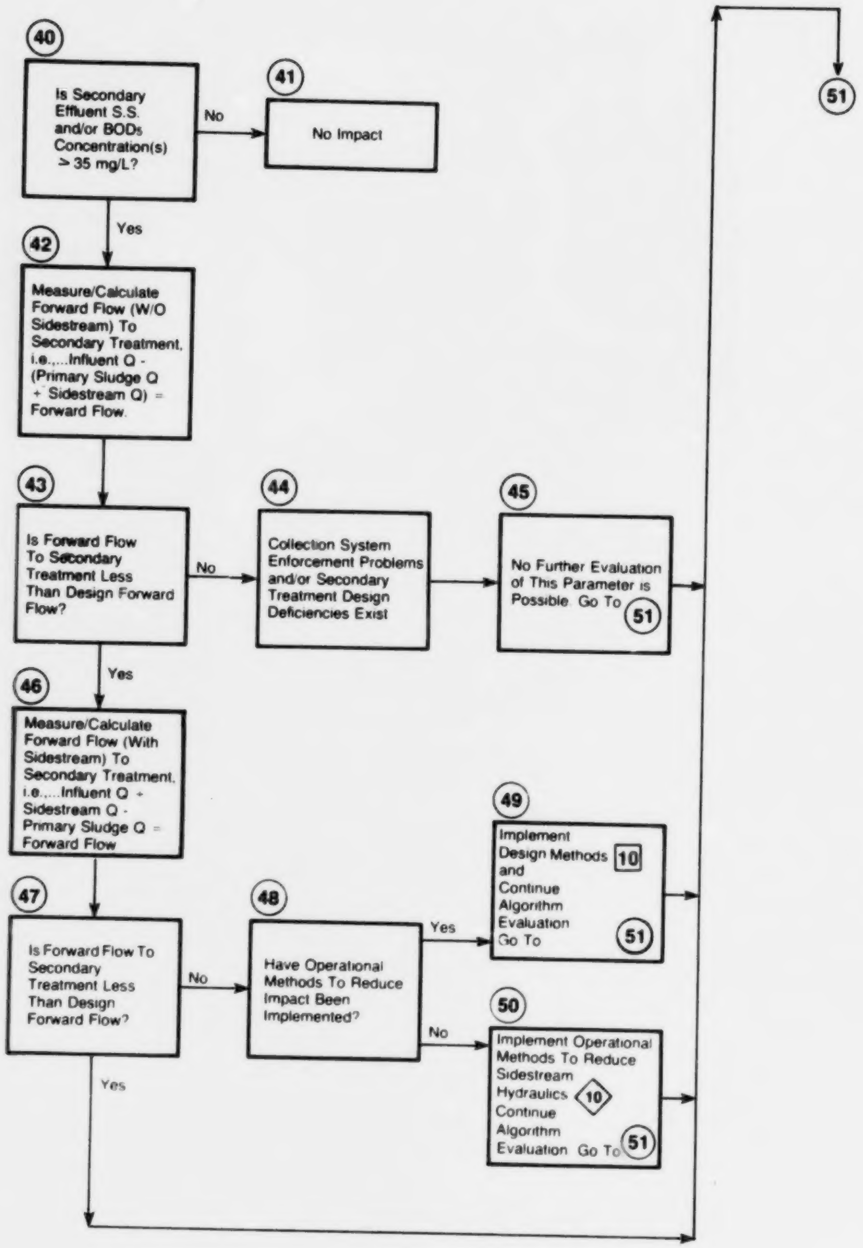
40
Is Secondary Effluent S.S. and/or BOD_5 Concentration(s) > 35 mg/L?
No
41
No Impact
Yes
42
Measure/Calculate Forward Flow (W/O Sidestream) To Secondary Treatment, i.e.,...Influent Q - (Primary Sludge Q + Sidestream Q) = Forward Flow.
43
Is Forward Flow To Secondary Treatment Less Than Design Forward Flow?
No
44
Collection System Enforcement Problems and/or Secondary Treatment Design Deficiencies Exist
45
No Further Evaluation of This Parameter is Possible. Go To 51
Yes
46
Measure/Calculate Forward Flow (With Sidestream) To Secondary Treatment, i.e.,...Influent Q + Sidestream Q - Primary Sludge Q = Forward Flow
47
Is Forward Flow To Secondary Treatment Less Than Design Forward Flow?
No
48
Have Operational Methods To Reduce Impact Been Implemented?
Yes
49
Implement Design Methods 10 and Continue Algorithm Evaluation Go To 51
No
50
Implement Operational Methods To Reduce Sidestream Hydraulics 10 Continue Algorithm Evaluation Go To 51
Yes
51

Figure 5. Evaluation of the sidestream impact on activated sludge.

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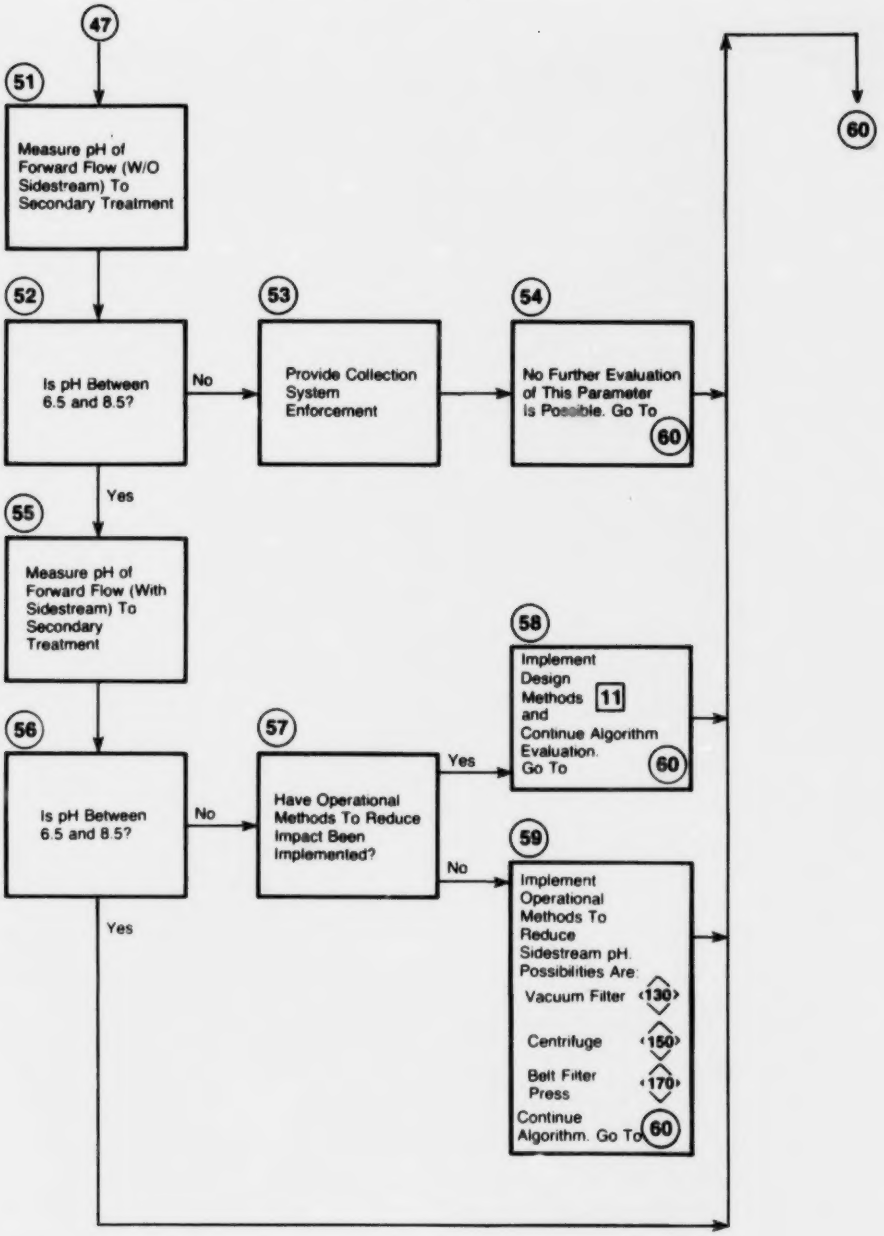
47
51
Measure pH of Forward Flow (W/O Sidestream) To Secondary Treatment
52
Is pH Between 6.5 and 8.5?
No
53
Provide Collection System Enforcement
54
No Further Evaluation of This Parameter Is Possible. Go To 60
Yes
55
Measure pH of Forward Flow (With Sidestream) To Secondary Treatment
56
Is pH Between 6.5 and 8.5?
No
57
Have Operational Methods To Reduce Impact Been Implemented?
Yes
58
Implement Design Methods 11 and Continue Algorithm Evaluation. Go To 60
No
59
Implement Operational Methods To Reduce Sidestream pH. Possibilities Are:
Vacuum Filter 130
Centrifuge 150
Belt Filter Press 170
Continue Algorithm. Go To 60
Yes
60

Figure 5. (continued)

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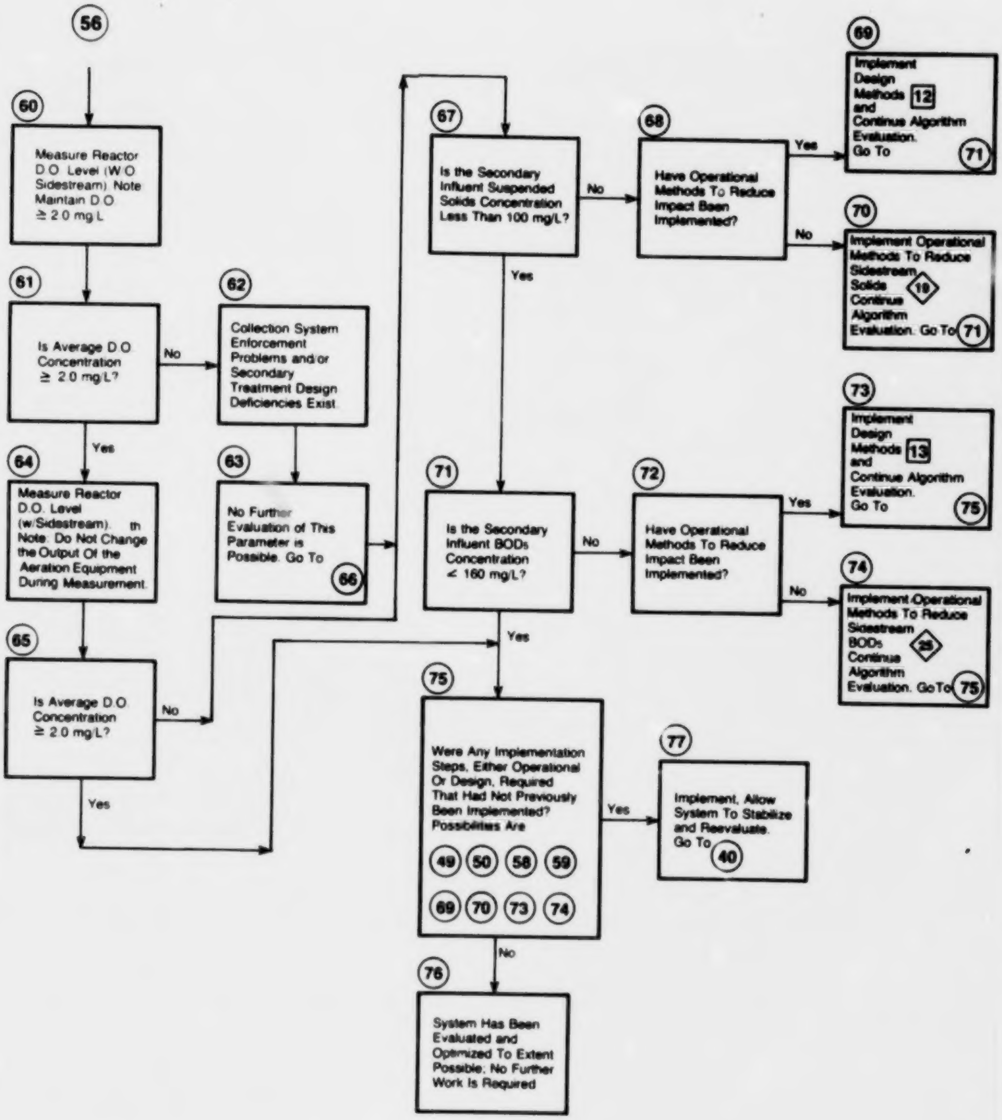
56
60
Measure Reactor D.O. Level (W/O Sidestream). Note: Maintain D.O. ≥ 2.0 mg/L
61
Is Average D.O. Concentration ≥ 2.0 mg/L?
No
62
Collection System Enforcement Problems and/or Secondary Treatment Design Deficiencies Exist.
63
No Further Evaluation of This Parameter is Possible. Go To 66
Yes
64
Measure Reactor D.O. Level (w/Sidestream). th Note: Do Not Change the Output Of the Aeration Equipment During Measurement.
65
Is Average D.O. Concentration ≥ 2.0 mg/L?
No
Yes
67
Is the Secondary Influent Suspended Solids Concentration Less Than 100 mg/L?
No
Yes
68
Have Operational Methods To Reduce Impact Been Implemented?
Yes
No
69
Implement Design Methods 12 and Continue Algorithm Evaluation. Go To 71
70
Implement Operational Methods To Reduce Sidestream Solids 19 Continue Algorithm Evaluation. Go To 71
71
Is the Secondary Influent BOD5 Concentration < 160 mg/L?
No
Yes
72
Have Operational Methods To Reduce Impact Been Implemented?
Yes
No
73
Implement Design Methods 13 and Continue Algorithm Evaluation. Go To 75
74
Implement Operational Methods To Reduce Sidestream BOD5 25 Continue Algorithm Evaluation. Go To 75
75
Were Any Implementation Steps, Either Operational Or Design, Required That Had Not Previously Been Implemented? Possibilities Are
49 50 58 59
69 70 73 74
Yes
77
Implement, Allow System To Stabilize and Reevaluate. Go To 40
No
76
System Has Been Evaluated and Optimized To Extent Possible; No Further Work Is Required

Figure 5. (continued)

sludge process until the aeration basin dissolved oxygen level is affected.

If the sidestream is found to affect the aeration basin dissolved oxygen concentration, then sidestream BOD_5 and suspended solids loadings must be determined.

Solids Loading--

Solids applied to the secondary treatment system in excess of the design loading may result in depression of dissolved oxygen levels in the aeration basin. In addition, the increase in solids loading will increase the amount of sludge that must be removed.

If the secondary influent suspended solids concentration is determined to be greater than 100 mg/L, then the recommended operational and/or design methods to reduce the impact should be implemented.

BOD_5 Loading--

BOD_5 applied to the secondary treatment system in excess of design loading may result in depression of dissolved oxygen levels in the aeration basin. If enough DO is present, then the increase in BOD_5 will create excess solids that in turn must be removed.

If secondary influent BOD_5 concentration is determined to be greater than 160 mg/L, then recommended operational and/or design methods to reduce the impact should be implemented.

Trickling Filter/Rotating Biological Contactor Evaluation of Sidestream Impact

Information contained in this section includes:

- Trickling Filter/RBC
- Discussion

The use of this algorithm is described in the User's Guide in Section 2 and an example is provided in Appendix B. Before the use of this algorithm, the user must develop and implement a Process Monitoring Program specific to the facility as is described in Section 2. The following algorithm is designed to apply to a large number of POTW's; therefore, it must be tailored to fit the user's requirements for the specific POTW.

The trickling filter/RBC algorithm is presented in Figure 6.

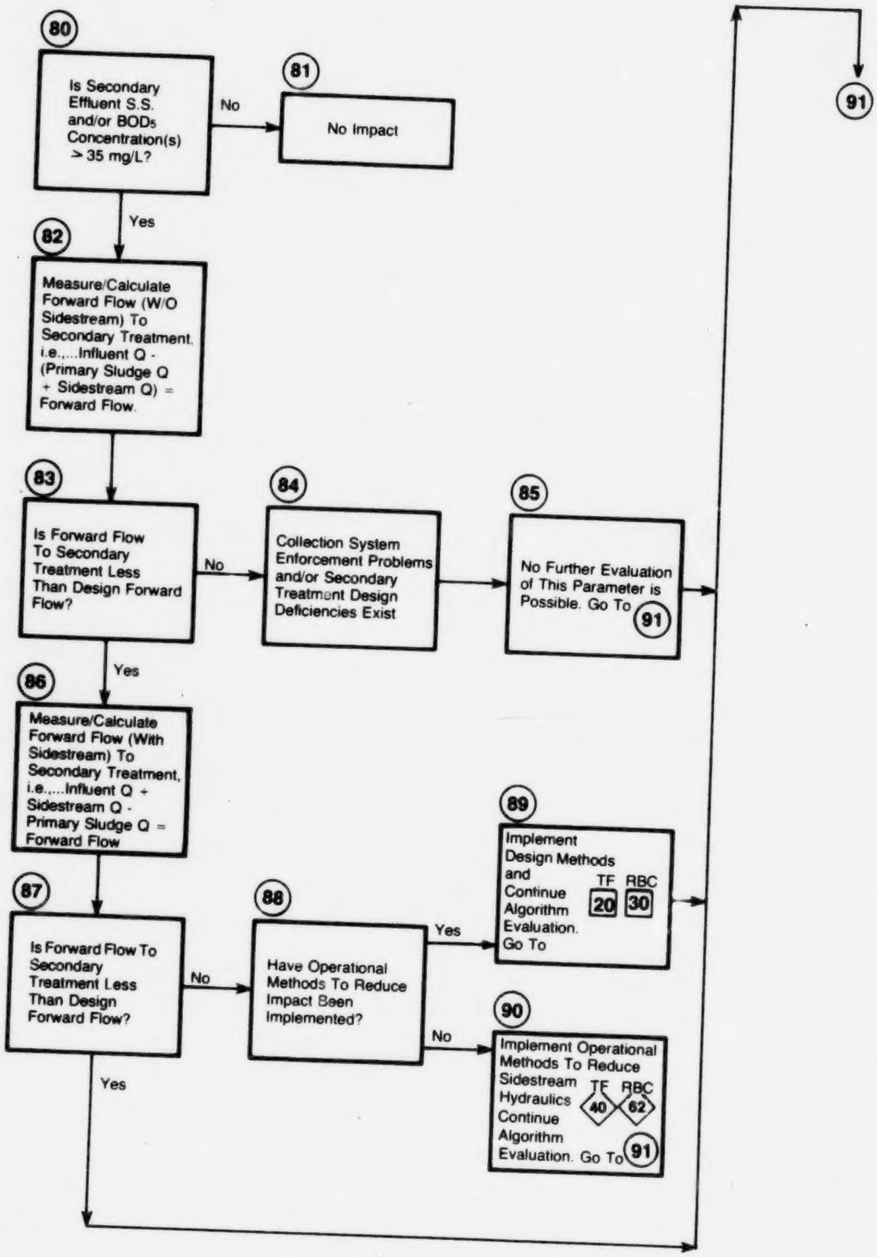
80
Is Secondary Effluent S.S. and/or BOD5 Concentration(s) > 35 mg/L?
No
81
No Impact
Yes
82
Measure/Calculate Forward Flow (W/O Sidestream) To Secondary Treatment, i.e.,...Influent Q - (Primary Sludge Q + Sidestream Q) = Forward Flow.
83
Is Forward Flow To Secondary Treatment Less Than Design Forward Flow?
No
84
Collection System Enforcement Problems and/or Secondary Treatment Design Deficiencies Exist
85
No Further Evaluation of This Parameter is Possible. Go To 91
Yes
86
Measure/Calculate Forward Flow (With Sidestream) To Secondary Treatment, i.e.,...Influent Q + Sidestream Q - Primary Sludge Q = Forward Flow
87
Is Forward Flow To Secondary Treatment Less Than Design Forward Flow?
No
88
Have Operational Methods To Reduce Impact Been Implemented?
Yes
89
Implement Design Methods and Continue Algorithm Evaluation. Go To
TF 20
RBC 30
No
90
Implement Operational Methods To Reduce Sidestream Hydraulics Continue Algorithm Evaluation. Go To 91
TF 40
RBC 62
Yes
91

Figure 6. Evaluation of the sidestream impact on trickling filters/rotating biological contactors.

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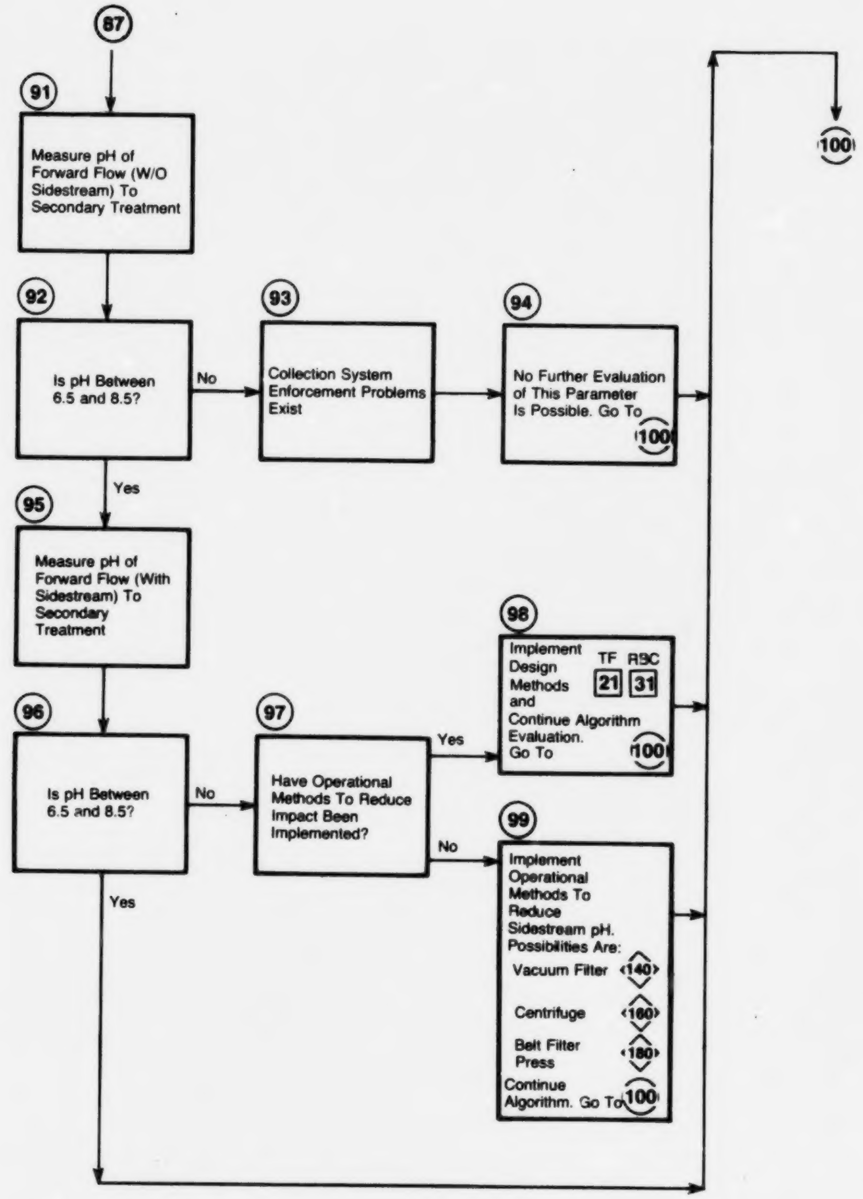
87
91
Measure pH of Forward Flow (W/O Sidestream) To Secondary Treatment
92
Is pH Between 6.5 and 8.5?
No
93
Collection System Enforcement Problems Exist
94
No Further Evaluation of This Parameter Is Possible. Go To 100
100
Yes
95
Measure pH of Forward Flow (With Sidestream) To Secondary Treatment
96
Is pH Between 6.5 and 8.5?
No
97
Have Operational Methods To Reduce Impact Been Implemented?
Yes
98
Implement Design Methods and Continue Algorithm Evaluation. Go To 100
TF 21
RBC 31
No
99
Implement Operational Methods To Reduce Sidestream pH. Possibilities Are:
Vacuum Filter 140
Centrifuge 160
Belt Filter Press 180
Continue Algorithm. Go To 100
Yes

Figure 6. (continued)

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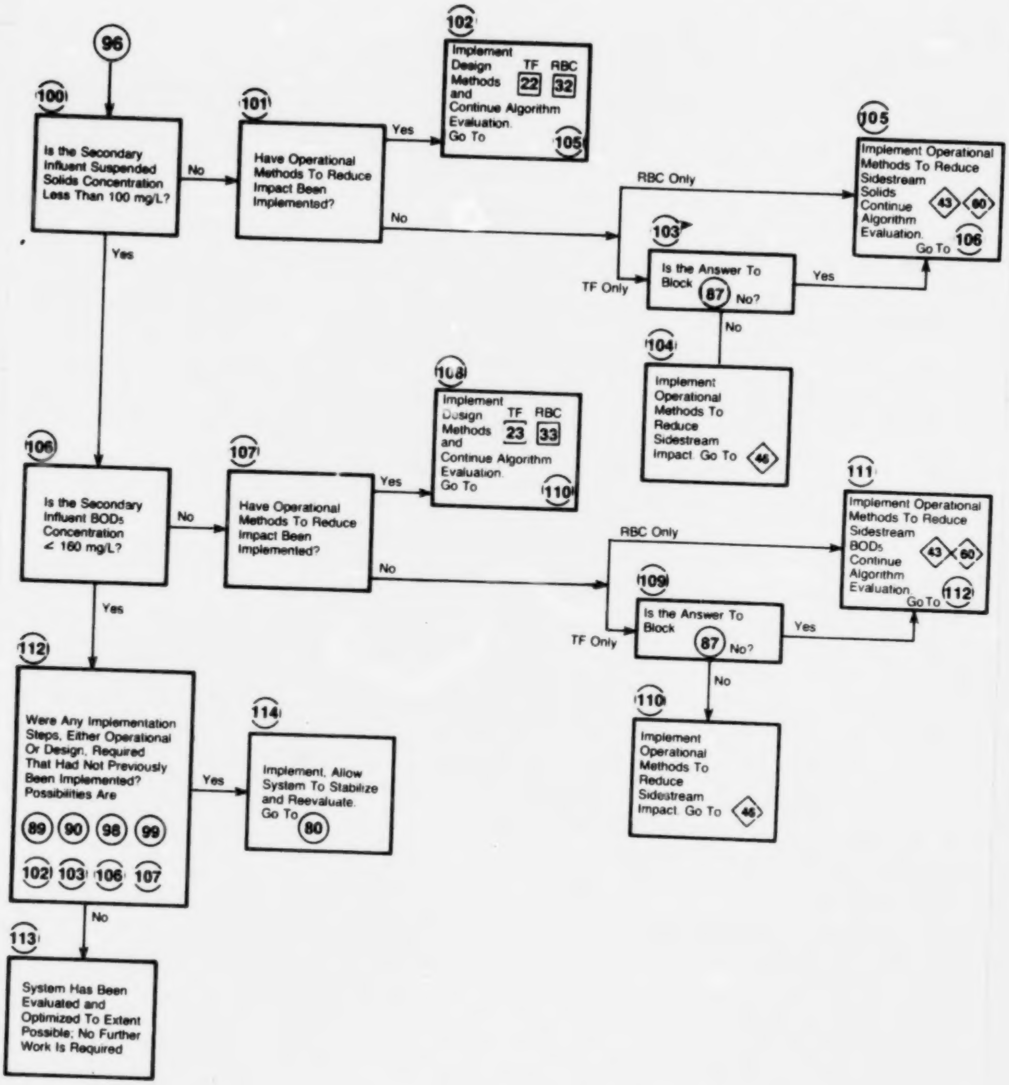
96
100
Is the Secondary Influent Suspended Solids Concentration Less Than 100 mg/L?
No
Yes
101
Have Operational Methods To Reduce Impact Been Implemented?
Yes
No
102
Implement Design Methods and Continue Algorithm Evaluation. Go To
TF 22
RBC 32
105
RBC Only
TF Only
103
Is the Answer To Block 87 No?
Yes
No
105
Implement Operational Methods To Reduce Sidestream Solids Continue Algorithm Evaluation. Go To 106
43
60
104
Implement Operational Methods To Reduce Sidestream Impact. Go To 46
106
Is the Secondary Influent BOD5 Concentration ≤ 160 mg/L?
No
Yes
107
Have Operational Methods To Reduce Impact Been Implemented?
Yes
No
108
Implement Design Methods and Continue Algorithm Evaluation. Go To
TF 23
RBC 33
110
RBC Only
TF Only
109
Is the Answer To Block 87 No?
Yes
No
111
Implement Operational Methods To Reduce Sidestream BOD5 Continue Algorithm Evaluation. Go To 112
43
60
110
Implement Operational Methods To Reduce Sidestream Impact. Go To 46
112
Were Any Implementation Steps, Either Operational Or Design, Required That Had Not Previously Been Implemented? Possibilities Are
89 90 98 99
102 103 106 107
Yes
No
114
Implement, Allow System To Stabilize and Reevaluate. Go To 80
113
System Has Been Evaluated and Optimized To Extent Possible; No Further Work Is Required

Figure 6. (continued)

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Trickling filters and rotating biological contactors are similar wastewater treatment processes (fixed film biological); therefore, a single algorithm was developed for use in evaluation of the processes.

Sidestream impacts have been identified that have the potential of decreasing performance of the biological and clarification processes, resulting in secondary effluent BOD_5 and suspended solids concentration equal to or greater than 35 mg/L.

The following impacts may all result in an increase in the secondary effluent BOD_5 and/or suspended solids concentration.

Flow (Hydraulic Loading)--

A hydraulic loading in excess of design loading will reduce the biological contact time. This reduction in biological contact time, in conjunction with a decrease in the secondary clarifier detention time, may result in decreased treatment efficiency with a corresponding increase in secondary effluent BOD_5 and suspended solids concentrations.

The hydraulic loading applied to the TF/RBC system is determined with and without the sidestream flow entering the system. This is done in order to rule out overload conditions that may be due to conditions not related to sidestreams recycle.

pH--

The pH of the process should be maintained between 6.5 and 8.5.

Sludge conditioning chemicals (i.e., lime, ferric chloride, ferrous sulfate, aluminum chloride, etc.) are used in a large number of treatment plants. As a result the potential exists for generation of a sidestream with a low or high pH.

The pH of the mainstream (TF/RBC) is determined with and without the addition of the sidestream flow. This is done in order to rule out abnormal pH conditions that may be due to conditions not related to sidestreams recycle.

Solids Loading--

The amount of solids applied to the trickling filter/rotating biological contactor in excess of design loading may affect the transfer of oxygen to the attached microorganisms. This effect is most often noted by pooling (TF only) or plugging of the media, in addition to the promotion of septic or anoxic conditions.

An excessive solids loading may affect the performance of the process, resulting in increased effluent BOD_5 and suspended solids concentration.

If the secondary influent suspended solids concentration is determined to be greater than 100 mg/L, then recommended operational and/or design methods to reduce the impact should be implemented.

BOD_5 Loading--

BOD_5 applied to the trickling filter/rotating biological contactor in excess of design loading may exceed the oxygen transfer capability of the system. This affect is most often noted by excessive sloughing and the attendant plugging and pooling (TF only), as well as by the promotion of septic or anoxic conditions.

An excessive BOD_5 loading may affect the performance of the process, resulting in increased effluent BOD_5 and suspended solids concentration.

If the secondary influent BOD_5 concentration is determined to be greater than 160 mg/L, then recommended operational and/or design methods to reduce the impact should be implemented.

SECTION 4

MAINSTREAM (OPERATIONAL) CONTROL ALGORITHMS

GENERAL

This section presents four algorithms that can be used as guides in making operational changes at the mainstream processes to control the impact of sidestreams. The mainstream control algorithms include:

1. Primary clarification (PC).
2. Activated sludge secondary treatment (AS).
3. Trickling filter secondary treatment (TF).
4. Rotating biological contactor secondary treatment (RBC).

Secondary clarification was considered as part of each secondary treatment process.

Each of the algorithms was developed to interface with evaluation algorithms developed in Section 3. During the evaluation of these mainstream treatment processes, the user is referred to specific algorithms contained in this section for operational methods to control the impacts determined.

PURPOSE

The purpose of the algorithms presented in this section is to provide guidance operational methodologies to control the impact of sidestreams on mainstream processes.

ALGORITHMS

The algorithms presented are each followed by a brief discussion of the methods recommended to reduce the impact of sidestreams on the mainstream treatment process.

Primary Clarification Control of Sidestream Impact

Information contained in this section includes:

- Primary Clarification Control Algorithm
- Discussion

The use of this algorithm is described in the User's Guide in Section 2 and an example is provided in Appendix B. Before the use of this algorithm, the user must develop and implement a Process Monitoring Program specific to the facility as is described in Section 2. The following algorithm is designed to apply to a large number of POTW's; therefore, it must be tailored to fit the user's requirements for the specific POTW.

The primary clarification control algorithm is presented in Figure 7.

The (primary clarifiers) control parameters deal principally with sludge removal. No other control parameters are generally available that would alter the operation of the primary clarifier to reduce the impact of sidestreams.

Sludge Removal--

Sludge removal from circular primary clarifiers should be scheduled to maintain a sludge blanket between one and three feet.

Sludge removal from rectangular clarifiers should be scheduled to maintain the sludge inventory in the sludge sump below the clarifier floor level.

The practice of keeping minimum quantities of sludge in the clarifiers will help in keeping the sludge "fresh" by reducing the opportunity for septicity. In addition, maintenance of a minimum sludge inventory in the primary clarifiers allows for an increased response time to the upset conditions before degradation of the primary effluent occurs. The maintenance of minimum sludge inventories can be accomplished by the following:

1. For plants equipped with variable rate sludge removal: Adjust primary sludge removal so that it occurs continuously. Allow only a one to two foot change in the sludge blanket depth. Continuous sludge removal can be achieved by adjusting the output of a sludge pump, telescopic valve, knife gate, etc. As an example, instead of removing sludge every 1/2 hour (on a timer controlled system) at a rate of 300 gpm, remove sludge continuously at a rate of 150 gpm. Plants with severe rag plugging problems may find it difficult to maintain constant flow. In this event, refer to the recommendations for constant rate sludge removal.

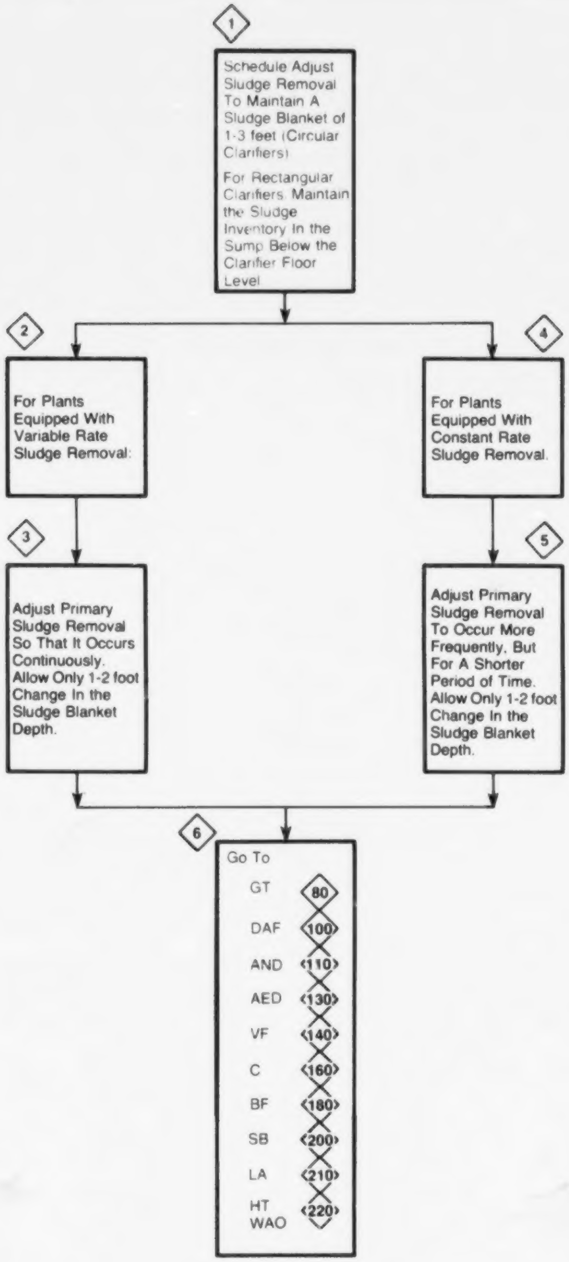
1
Schedule Adjust Sludge Removal To Maintain A Sludge Blanket of 1-3 feet (Circular Clarifiers)
For Rectangular Clarifiers Maintain the Sludge Inventory In the Sump Below the Clarifier Floor Level
2
For Plants Equipped With Variable Rate Sludge Removal:
4
For Plants Equipped With Constant Rate Sludge Removal.
3
Adjust Primary Sludge Removal So That It Occurs Continuously. Allow Only 1-2 foot Change In the Sludge Blanket Depth.
5
Adjust Primary Sludge Removal To Occur More Frequently, But For A Shorter Period of Time. Allow Only 1-2 foot Change In the Sludge Blanket Depth.
6
Go To
GT 80
DAF 100
AND 110
AED 130
VF 140
C 160
BF 180
SB 200
LA 210
HT WAO 220

Figure 7. Operational methods to reduce the impact of sidestreams on primary clarifiers.

2. For plants equipped with constant rate sludge removal: Adjust primary sludge removal to occur more frequently but for a shorter period of time. Allow only a one to two foot change in the sludge blanket depth. As an example, instead of removing large quantities of sludge once per day (usually during day shift), remove smaller amounts of sludge once or twice each shift. Note that the same rate of removal is maintained. This would apply to those plants equipped with constant speed pumps, plug valve sludge removal or similar removal strategies.

The operational methods generally available at the primary clarifier to reduce the sidestream impact have been presented in this subsection. To lessen impacts further, select from the algorithm those operations that exist in the specific treatment system, and refer to the algorithm indicated.

Activated Sludge Control of Sidestream Impact

Information contained in this section includes:

- Activated Sludge Control
- Discussion

The use of this algorithm is described in the User's Guide in Section 2 and an example is provided in Appendix B. Before the use of this algorithm, the user must develop and implement a Process Monitoring Program specific to the facility as is described in Section 2. The following algorithm is designed to apply to a large number of POTW's; therefore, it must be tailored to fit the user's requirements for the specific POTW.

The activated sludge algorithm is presented in Figure 8.

Of the secondary treatment processes considered, the activated sludge secondary treatment process has the greatest degree of flexibility to compensate for sidestream impacts.

The greater flexibility is achieved because, unlike trickling filters and rotating biological contactors, operational controls are available for physical and biological conditions.

Hydraulic Loading Control Methods--

If the treatment system is equipped with platform mounted aerators, it is sensitive to level changes that may occur in the aeration basin. Basin level changes due to sidestream should be determined. If the level in the basin is changing by ± three to

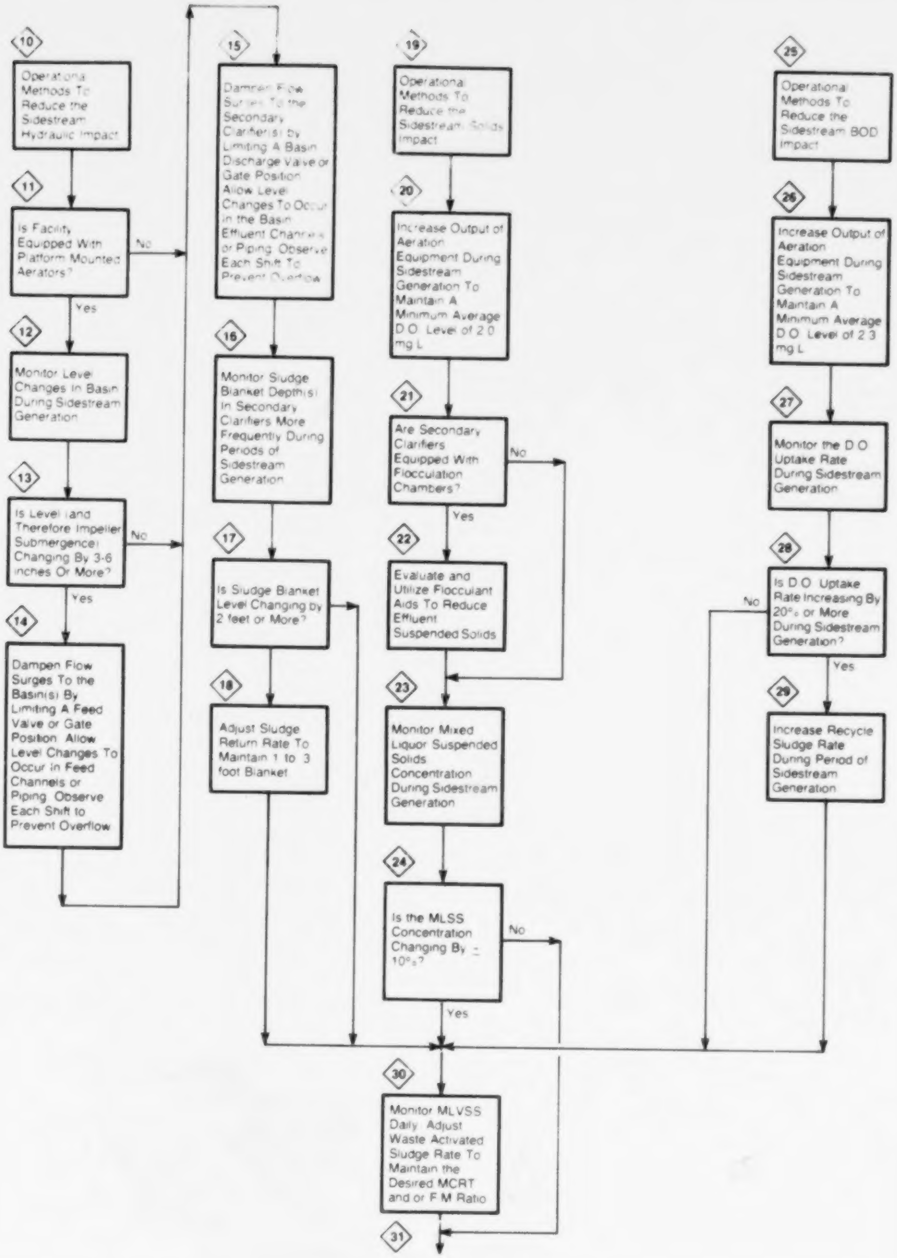
10
Operational Methods To Reduce the Sidestream Hydraulic Impact
11
Is Facility Equipped With Platform Mounted Aerators?
No
Yes
12
Monitor Level Changes In Basin During Sidestream Generation
13
Is Level (and Therefore Impeller Submergence) Changing By 3-6 inches Or More?
No
Yes
14
Dampen Flow Surges To the Basin(s) By Limiting A Feed Valve or Gate Position. Allow Level Changes To Occur In Feed Channels or Piping. Observe Each Shift to Prevent Overflow
15
Dampen Flow Surges To the Secondary Clarifier(s) by Limiting A Basin Discharge Valve or Gate Position. Allow Level Changes To Occur in the Basin Effluent Channels or Piping. Observe Each Shift To Prevent Overflow
16
Monitor Sludge Blanket Depth(s) In Secondary Clarifiers More Frequently During Periods of Sidestream Generation
17
Is Sludge Blanket Level Changing by 2 feet or More?
18
Adjust Sludge Return Rate To Maintain 1 to 3 foot Blanket
19
Operational Methods To Reduce the Sidestream Solids Impact
20
Increase Output of Aeration Equipment During Sidestream Generation To Maintain A Minimum Average D.O. Level of 2.0 mg/L
21
Are Secondary Clarifiers Equipped With Flocculation Chambers?
No
Yes
22
Evaluate and Utilize Flocculant Aids To Reduce Effluent Suspended Solids
23
Monitor Mixed Liquor Suspended Solids Concentration During Sidestream Generation
24
Is the MLSS Concentration Changing By ± 10%?
No
Yes
25
Operational Methods To Reduce the Sidestream BOD Impact
26
Increase Output of Aeration Equipment During Sidestream Generation To Maintain A Minimum Average D.O. Level of 2.3 mg/L
27
Monitor the D.O. Uptake Rate During Sidestream Generation
28
Is D.O. Uptake Rate Increasing By 20% or More During Sidestream Generation?
No
Yes
29
Increase Recycle Sludge Rate During Period of Sidestream Generation
30
Monitor MLVSS Daily. Adjust Waste Activated Sludge Rate To Maintain the Desired MCRT and/or F/M Ratio
31

Figure 8. Operational methods to reduce sidestream impacts on activated sludge.

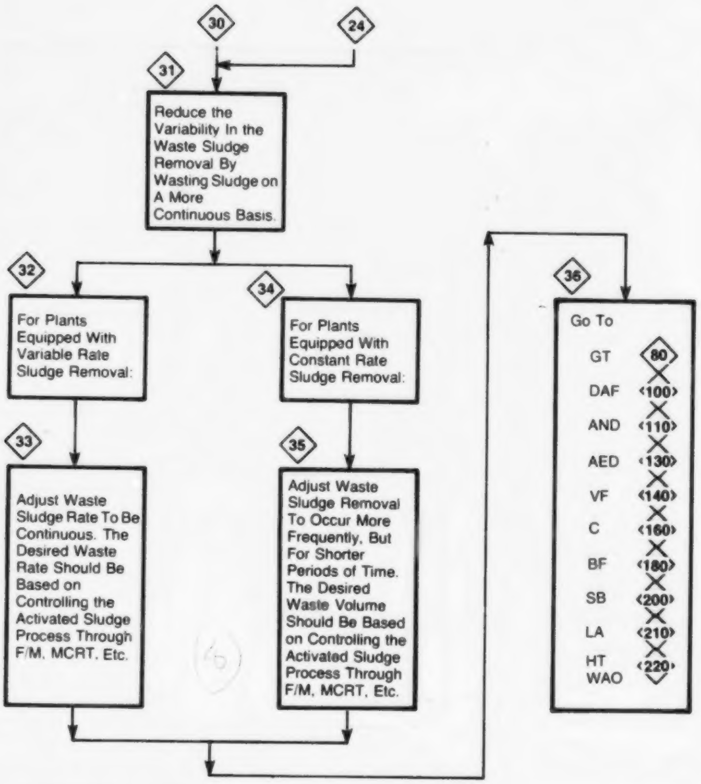
30
24
31
Reduce the Variability In the Waste Sludge Removal By Wasting Sludge on A More Continuous Basis.
32
For Plants Equipped With Variable Rate Sludge Removal:
34
For Plants Equipped With Constant Rate Sludge Removal:
33
Adjust Waste Sludge Rate To Be Continuous. The Desired Waste Rate Should Be Based on Controlling the Activated Sludge Process Through F/M, MCRT, Etc.
35
Adjust Waste Sludge Removal To Occur More Frequently, But For Shorter Periods of Time. The Desired Waste Volume Should Be Based on Controlling the Activated Sludge Process Through F/M, MCRT, Etc.
36
Go To
GT 80
DAF 100
AND 110
AED 130
VF 140
C 160
BF 180
SB 200
LA 210
HT WAO 220

Figure 8. (continued)

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six inches, then operational methods should be implemented to control impact.

One method for confirming the sidestream impact on the aerators is to measure the amperage on an aerator over a 24-hour period. Intermittent sidestream flows that affect the basin by ± three to six inches should be reflected in the amperage readings.

An operational method to reduce the impact caused by changes in hydraulic loading due to sidestream flows is to allow the level changes to occur elsewhere. However, most treatment systems are not equipped with equalization basins. Some dampening of flow surges caused by sidestreams can be achieved by allowing level changes to occur in the aeration basin feed channels or piping.

Flow surges that pass through the aeration basin enter the secondary clarifiers. These surges may affect settling performance in the clarifiers. The hydraulic surges can be dampened to some degree by allowing level changes to occur in aeration basin effluent channels or piping.

Changes in hydraulic loading (flow) due to sidestreams will create variations in the rate at which mixed liquor is discharged to the secondary clarifiers. This in turn will cause variations in the sludge blanket depth. If this condition is not compensated for, as needed, by adjusting the sludge recycle rate, the sludge blanket will become excessive, resulting in high solid losses to the effluent.

Solids Loading Control Methods--

An increase in the amount of solids received by the activated sludge system may result in a decrease in normally maintained DO levels (assumed to be 2.0 mg/L). In order to compensate for the depression in DO, output of the aeration equipment (blowers or aerators) should be increased.

The nature of the suspended solids that are returned to the system via sidestreams may be such that they will resist settling in the secondary clarifiers. Note that the majority of the solids that are returning in sidestream flows are "fines" that have escaped capture in solids handling processes.

In order to limit impact of sidestream solids, plants should evaluate and utilize flocculant aids in or near the secondary clarifiers.

BOD_5 Loading Control Methods--

An increase in the amount of BOD_5 received by the activated sludge system may result in a decrease in normally maintained DO levels. In order to compensate for the depression in DO, output of the aeration equipment (blowers or aerators) should be increased.

Large increases in the BOD_5 applied to the system due to sidestreams may represent a shock load to the system. An indication of the beginning of a shock load would be a 20 percent or greater increase in the average DO uptake when the sidestream is being recycled.

Assuming that sufficient aeration capacity is available when a shock load is noted, the recycle sludge rate should be increased to "spread" the loading and to bring a greater amount of acclimated microorganisms into contact with the incoming BOD_5.

Hydraulic, Solids, and BOD_5 Loading Control Methods--

If the aeration basin mixed liquor suspended solids concentration is changing by ± 10 percent during periods of sidestream recycling and/or hydraulic or BOD_5 overload conditions are noted, adjustments will be required in the sludge wasting rate.

An increase in solids loading will require an increase in the waste rate. A hydraulic overload condition may require a decrease in the waste rate. A BOD_5 overload condition will require an increase in the waste rate. All waste rate adjustments should be based on an operating parameter for activated sludge systems such as MCRT (Mean Cell Residence Time) or F/M (Food to Microorganism) ratio.

The variability in the waste sludge removal should be reduced as much as possible, i.e., sludge should be removed as continuously as possible. This will help to avoid surges in the systems that are receiving the sludge (i.e., thickeners). The variability can be reduced by the following:

1. For plants equipped with variable rate sludge removal: Adjust secondary sludge removal so that it occurs continuously. Continuous sludge removal can be achieved by adjusting the output of a sludge pump, telescopic valve, knife gate, etc. The sludge wastage should be based on an operating parameter such as MCRT or F/M. The use of such a parameter will define the mass or volume of sludge to be removed. The user should, through proper adjustment of the sludge removal equipment (pumps, valves, etc.), control the

removal rate to remove the desired sludge mass. As an example, instead of removing sludge every 1/2 hour (on a timer controlled system) at a rate of 300 gpm, remove sludge continuously at a rate of 150 gpm.

2. For plants equipped with constant rate sludge removal: Adjust secondary sludge removal to occur more frequently but for a shorter period of time. This would apply to those plants equipped with constant speed pumps, plug valve sludge removal or similar removal strategies. As an example, instead of removing large quantities of sludge once per day (usually during day shift) remove smaller amounts of sludge once or twice each shift. The sludge wastage should be based on an operating parameter such as MCRT or F/M. The use of such a parameter will define the mass or volume of sludge to be removed. The user should adjust the frequency of equipment operation to remove the desired sludge mass.

The operational methods generally available in the activated sludge system to reduce the sidestream impact have been presented in this subsection. To lessen impacts further, those operations that exist in the specific treatment system must be identified, and methods given to improve the quality of the sidestream must be investigated.

Control of Sidestream Impact for Trickling Filter

Information contained in this section includes:

- Trickling Filter Operation
- Discussion

The use of this algorithm is described in the User's Guide in Section 2 and an example is provided in Appendix B. Before the use of this algorithm, the user must develop and implement a Process Monitoring Program specific to the facility as is described in Section 2. The following algorithm is designed to apply to a large number of POTW's; therefore, it must be tailored to fit the user's requirements for the specific POTW.

The trickling filter algorithm is presented in Figure 9.

Trickling filter systems have far less flexibility to compensate for sidestream impacts than do activated sludge systems. The operational controls generally available at the trickling filters deal principally with recycle flow adjustment.

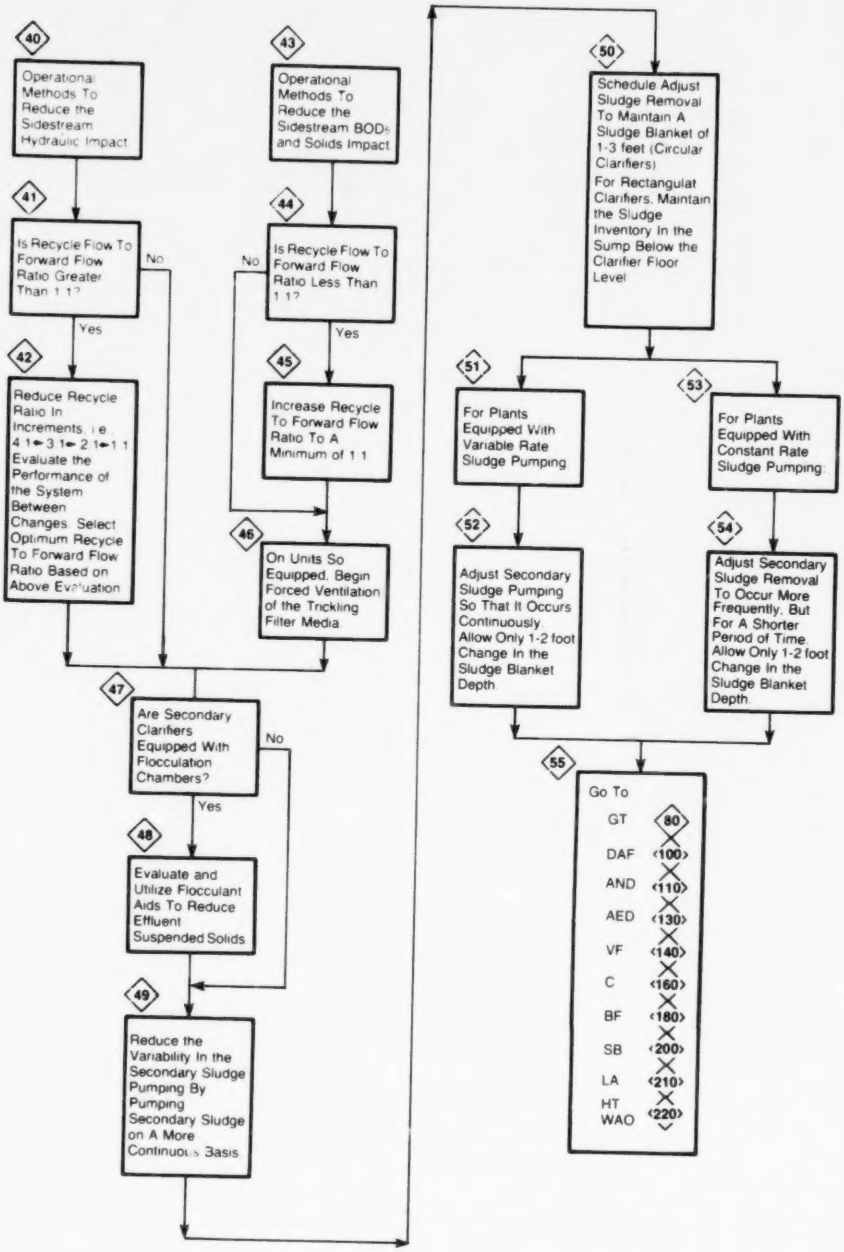

40
Operational Methods To Reduce the Sidestream Hydraulic Impact
41
Is Recycle Flow To Forward Flow Ratio Greater Than 1:1?
No
Yes
42
Reduce Recycle Ratio In Increments, i.e., 4:1→3:1→2:1→1:1. Evaluate the Performance of the System Between Changes. Select Optimum Recycle To Forward Flow Ratio Based on Above Evaluation
43
Operational Methods To Reduce the Sidestream BOD5 and Solids Impact
44
Is Recycle Flow To Forward Flow Ratio Less Than 1:1?
No
Yes
45
Increase Recycle To Forward Flow Ratio To A Minimum of 1:1
46
On Units So Equipped, Begin Forced Ventilation of the Trickling Filter Media
47
Are Secondary Clarifiers Equipped With Flocculation Chambers?
No
Yes
48
Evaluate and Utilize Flocculant Aids To Reduce Effluent Suspended Solids
49
Reduce the Variability In the Secondary Sludge Pumping By Pumping Secondary Sludge on A More Continuous Basis
50
Schedule Adjust Sludge Removal To Maintain A Sludge Blanket of 1-3 feet (Circular Clarifiers)
For Rectangulat Clarifiers, Maintain the Sludge Inventory In the Sump Below the Clarifier Floor Level
51
For Plants Equipped With Variable Rate Sludge Pumping
52
Adjust Secondary Sludge Pumping So That It Occurs Continuously. Allow Only 1-2 foot Change In the Sludge Blanket Depth
53
For Plants Equipped With Constant Rate Sludge Pumping:
54
Adjust Secondary Sludge Removal To Occur More Frequently, But For A Shorter Period of Time. Allow Only 1-2 foot Change In the Sludge Blanket Depth
55
Go To
GT 80
DAF 100
AND 110
AED 130
VF 140
C 160
BF 180
SB 200
LA 210
HT WAO 220

Figure 9. Operational methods to reduce the sidestream impact on trickling filters.

Operational methods to reduce the impact due to hydraulic and BOD/suspended solids increases are opposite, i.e., one method reduces recycle flow while the other increases recycle flow. If, during the evaluation of the process, it is determined that the filter unit is hydraulically and organically overloaded, no changes in the recycle flow rate may be merited. This condition should therefore be corrected by design modifications.

Hydraulic Loading Control Methods--

If the ratio is greater than 1:1, reduce the recycle to forward flow rate in increments to compensate for the sidestream hydraulics. The reduction in recycle required to operate the filter at or below the design hydraulic loading can be calculated by actual hydraulic loading - design loading excess loading. The excess loading is the amount of reduction required in the recycle flow. Note that if the hydraulic impact occurs intermittently (because the sidestream is occurring intermittently), it may be practical to reduce the trickling filter recycle flow only during periods when the sidestream is being produced.

Solids and BOD_5 Control Methods--

If the ratio is less than 1:1, increase the recycle ratio to a minimum of 1:1. The recycle ratio can be increased above 1:1 if the trickling filter unit is designed to accommodate the hydraulic increase.

When making changes to the recycle flow, do so in increments and evaluate the performance of the filter unit after each change. Allow at least one day after a change is made before evaluating the filter unit.

Note that the increase in recycle rate will help to "spread" or dilute the BOD_5 and suspended solids loading, thereby limiting a shock or oxygen-limited loading condition.

The nature of the suspended solids that are returned to the system via sidestreams may be such that they will resist settling in the secondary clarifiers. Note that the majority of the solids that are returning in sidestream flows are "fines" that have escaped capture in solids handling processes.

In order to limit the impact of sidestream solids, plants should evaluate and utilize flocculant aids in or near the secondary clarifiers.

The variability in the waste sludge removal should be reduced as much as possible, i.e., sludge should be removed as continuously as possible. This will help to reduce surges in the systems that are receiving the sludge (i.e., thickeners).

Sludge removal from circular secondary clarifiers should be scheduled to maintain a sludge blanket between one and three feet. Sludge removal from rectangular clarifiers should be scheduled to maintain sludge inventory in the sludge sump below the clarifier floor level.

The practice of keeping minimum quantities of sludge in the clarifiers will help in keeping the sludge "fresh" by reducing the opportunity for septicity. In addition, the maintenance of a minimum sludge inventory in the secondary clarifiers allows for an increased response time to the upset conditions before degradation of the secondary effluent occurs. The maintenance of minimum sludge inventories can be accomplished by the following:

1. For plants equipped with variable rate sludge removal: Adjust secondary sludge removal so that it occurs continuously. Allow only a one to two foot change in the sludge blanket depth. Continuous sludge removal can be achieved by adjusting the output of a sludge pump, telescopic valve, knife gate, etc. As an example, instead of removing sludge every 1/2 hour (on a timer controlled system) at a rate of 300 gpm, remove sludge continuously at a rate of 150 gpm.

2. For plants equipped with constant rate sludge removal: Adjust secondary sludge removal to occur more frequently but for a shorter period of time. Allow only a one to two foot change in the sludge blanket depth. As an example, instead of removing large quantities of sludge once per day (usually during day shift), remove smaller amounts of sludge once or twice each shift. This applies to those plants equipped with constant speed pumps, plug valve sludge removal, or similar removal strategies.

Rotating Biological Contactor Control of Sidestream Impact

Information contained in this section includes:

- RBC Control
- Discussion

The use of this algorithm is described in the User's Guide in Section 2 and an example is provided in Appendix B. Before the use of this algorithm, the user must develop and implement a

Process Monitoring Program specific to the facility as is described in Section 2. The following algorithm is designed to apply to a large number of POTW's; therefore, it must be tailored to fit the user's requirements for the specific POTW.

The rotating biological contactor algorithm is presented in Figure 10.

Typical installations of RBC units do not permit a wide range of adjustments to compensate for process changes, i.e., impacts due to sidestreams. The operator has greater flexibility to compensate for sidestream impacts at the secondary clarifiers. Those methods that are generally available follow.

Hydraulic Loading Control Methods--
Hydraulic surges imposed on the RBC units can be dampened to some degree by installing baffles in influent channels, where possible. This will allow level changes to occur in influent channels and help to smooth out (equalize) hydraulic peaks created by sidestreams.

Solids and BOD_5 Loading Control Methods--
Where equipped to do so, increase rotational speed of the unit. For units designed with a fixed speed, consult the manufacturer before making speed changes. The speed changes should be incremental, followed by an evaluation of the process performance.

Air drive units can be increased in speed by increasing air output (where excess capacity is available) to each unit.

Variable speed, mechanical drive systems can be varied by changing handwheel settings.

Belt drive units (with constant speed motor drives) can be varied by changing sheaves.

Fixed speed, direct drive units cannot be easily varied, thus requiring a design modification to accomplish speed changes.

Hydraulic, Solids, and BOD_5 Loading Control Methods--
The variability in waste sludge removal from the secondary clarifiers should be reduced as much as possible, i.e., sludge should be removed as continuously as possible. This will help to reduce surges in the systems that are receiving the sludge (i.e., thickeners).

Sludge removal from circular secondary clarifiers should be scheduled to maintain a sludge blanket between one and three

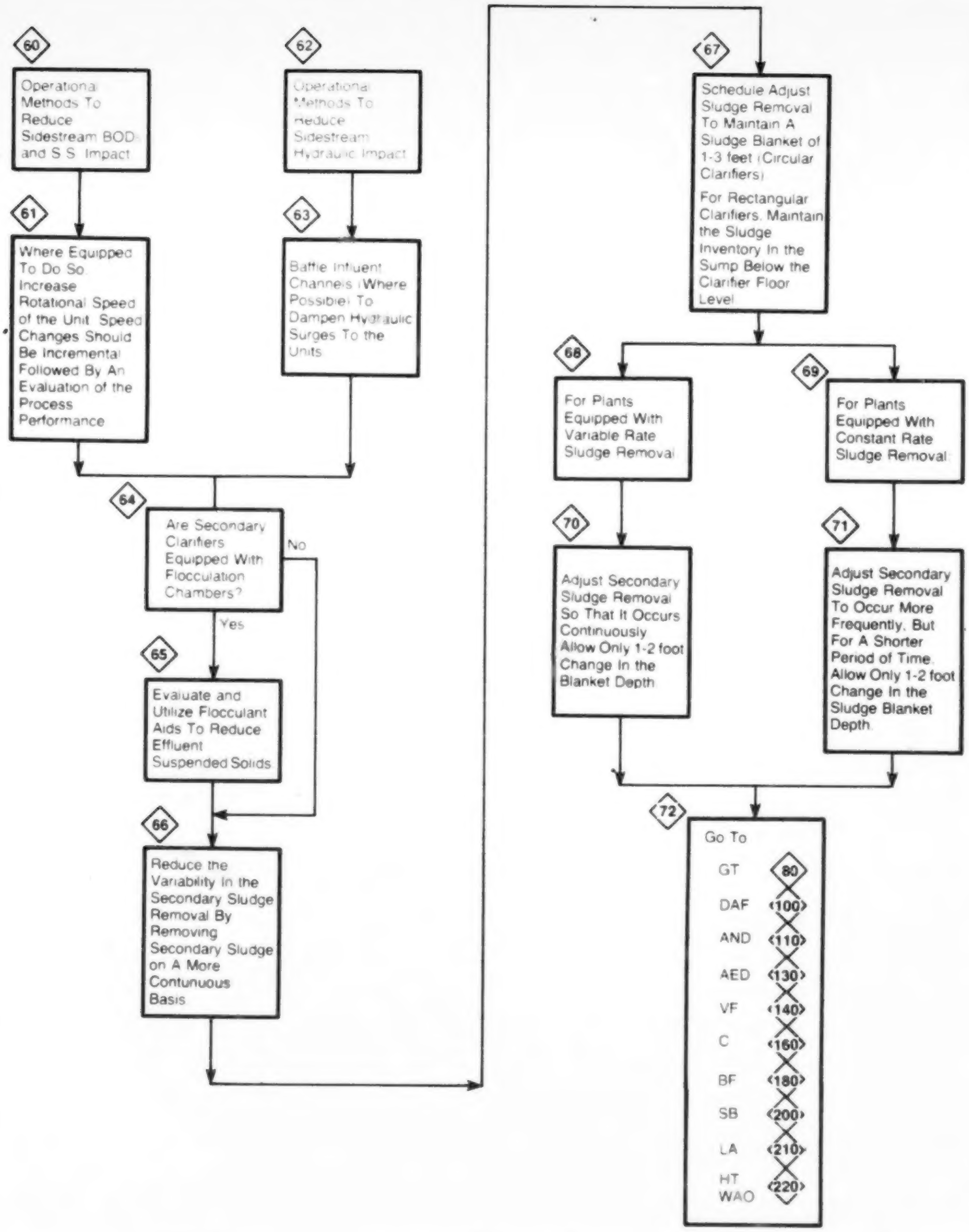

60
Operational Methods To Reduce Sidestream BOD and S.S. Impact
61
Where Equipped To Do So, Increase Rotational Speed of the Unit. Speed Changes Should Be Incremental Followed By An Evaluation of the Process Performance
62
Operational Methods To Reduce Sidestream Hydraulic Impact
63
Baffle Influent Channels (Where Possible) To Dampen Hydraulic Surges To the Units
64
Are Secondary Clarifiers Equipped With Flocculation Chambers?
No
Yes
65
Evaluate and Utilize Flocculant Aids To Reduce Effluent Suspended Solids
66
Reduce the Variability In the Secondary Sludge Removal By Removing Secondary Sludge on A More Contunuous Basis
67
Schedule Adjust Sludge Removal To Maintain A Sludge Blanket of 1-3 feet (Circular Clarifiers)
For Rectangular Clarifiers, Maintain the Sludge Inventory In the Sump Below the Clarifier Floor Level
68
For Plants Equipped With Variable Rate Sludge Removal
69
For Plants Equipped With Constant Rate Sludge Removal
70
Adjust Secondary Sludge Removal So That It Occurs Continuously. Allow Only 1-2 foot Change In the Blanket Depth
71
Adjust Secondary Sludge Removal To Occur More Frequently, But For A Shorter Period of Time. Allow Only 1-2 foot Change In the Sludge Blanket Depth.
72
Go To
GT 80
DAF 100
AND 110
AED 130
VF 140
C 160
BF 180
SB 200
LA 210
HT WAO 220

Figure 10. Operational methods to reduce the sidestream impact on rotating biological contactors.

feet. Sludge removal from rectangular clarifiers should be scheduled to maintain sludge inventory in the sludge sump below the clarifier floor level.

The maintenance of minimum quantities of sludge in the clarifiers will help in keeping the sludge "fresh" by reducing the opportunity for septicity. In addition, maintenance of a minimum sludge inventory in the secondary clarifiers allows for an increased response time to upset conditions before degradation of the secondary effluent occurs. The maintenance of minimum sludge inventories can be accomplished by the following:

1. For plants equipped with variable rate sludge removal: Adjust secondary sludge removal so that it occurs continuously. Allow only a one to two foot change in the sludge blanket depth. Continuous sludge removal can be achieved by adjusting the output of a sludge pump, telescopic valve, knife gate, etc. As an example, instead of removing sludge every 1/2 hour (on a timer controlled system) at a rate of 300 gpm, remove sludge continuously at a rate of 150 gpm.

2. For plants equipped with constant rate sludge removal: Adjust secondary sludge removal to occur more frequently but for a shorter period of time. Allow only a one to two foot change in the sludge blanket depth. As an example, instead of removing large quantities of sludge once per day (usually during day shift), remove smaller amounts of sludge once or twice each shift. This applies to those plants equipped with constant speed pumps, plug valve sludge removal or similar removal strategies.

SECTION 5

SIDESTREAM (OPERATIONAL) CONTROL ALGORITHMS

GENERAL

This section presents ten algorithms that can be used as guides in making operational changes at the sidestream generator to control the impact of sidestreams on mainstream processes. Sidestream control algorithms have been prepared for the following:

1. Gravity thickening (GT).
2. Dissolved air flotation (DAF).
3. Anaerobic digestion (AnD).
4. Aerobic digestion (AeD).
5. Vacuum filtration (VF).
6. Centrifuge (C).
7. Belt filters (BF).
8. Sand drying beds (SB).
9. Lagoons (LA).
10. Heat treatment/wet air oxidation (HT/WAO).

Each of these algorithms was developed to interface with the evaluation algorithms developed in Section 3. The sidestream algorithms presented in this section were developed to be a continuation of the mainstream operational control algorithms presented in Section 4.

PURPOSE

The purpose of the algorithms presented in this section is to provide guidance operational methodologies to control sidestreams at the source.

Gravity Thickening Control of Sidestream Impact

Information contained in this section includes:

- Gravity Thickening Control
- Discussion

The use of this algorithm is described in the User's Guide in Section 2 and an example is provided in Appendix B. Prior to the use of this algorithm, the user must develop and implement a Process Monitoring Program specific to the facility as is described in Section 2. The following algorithm is designed to apply to a large number of POTW's; therefore, it must be tailored to fit the user's requirements for the specific POTW.

The gravity thickening control algorithm is presented in Figure 11.

Dilution Water--

Dilution water (usually recycled plant effluent) is often used at gravity thickeners to improve sludge settleability. The improvement is usually brought about by washing out the "fines" in the sludge that often hamper settling, and by reducing the opportunity for septicity.

The use of dilution water often greatly increases the sidestream flow (thickener overflow), and purges solids from the thickeners that will resist settling and treatment in the mainstream processes. For these reasons, the use of dilution water should be minimized or eliminated. The benefits associated with dilution water use can often be achieved by other means. Alternate means will be discussed in the following text.

Sludge Blending--

Some treatment systems equipped with multiple thickeners are provided with the capability of segregating primary and secondary sludge thickening activities. This mode of operation may result in one thickener (usually the one receiving primary sludge) operating reasonably well while the performance of the other thickener (usually the one receiving secondary sludge) is poor. The result is varying thickener performances, as well as different sidestream qualities.

The user should evaluate this mode of operation (segregated sludge thickening) to determine if the overall sidestream quality can be improved. As part of the evaluation, the suspended solids concentration should be determined for each thickener overflow. If it is determined that the average overflow solids concentrations differ by ± 10 percent the sludge blending should be considered. However, before any operational changes are made, laboratory jar tests should be performed to determine if sludge blending will result in an acceptable thickening performance and in a reduction in the average sidestream suspended solids concentration.

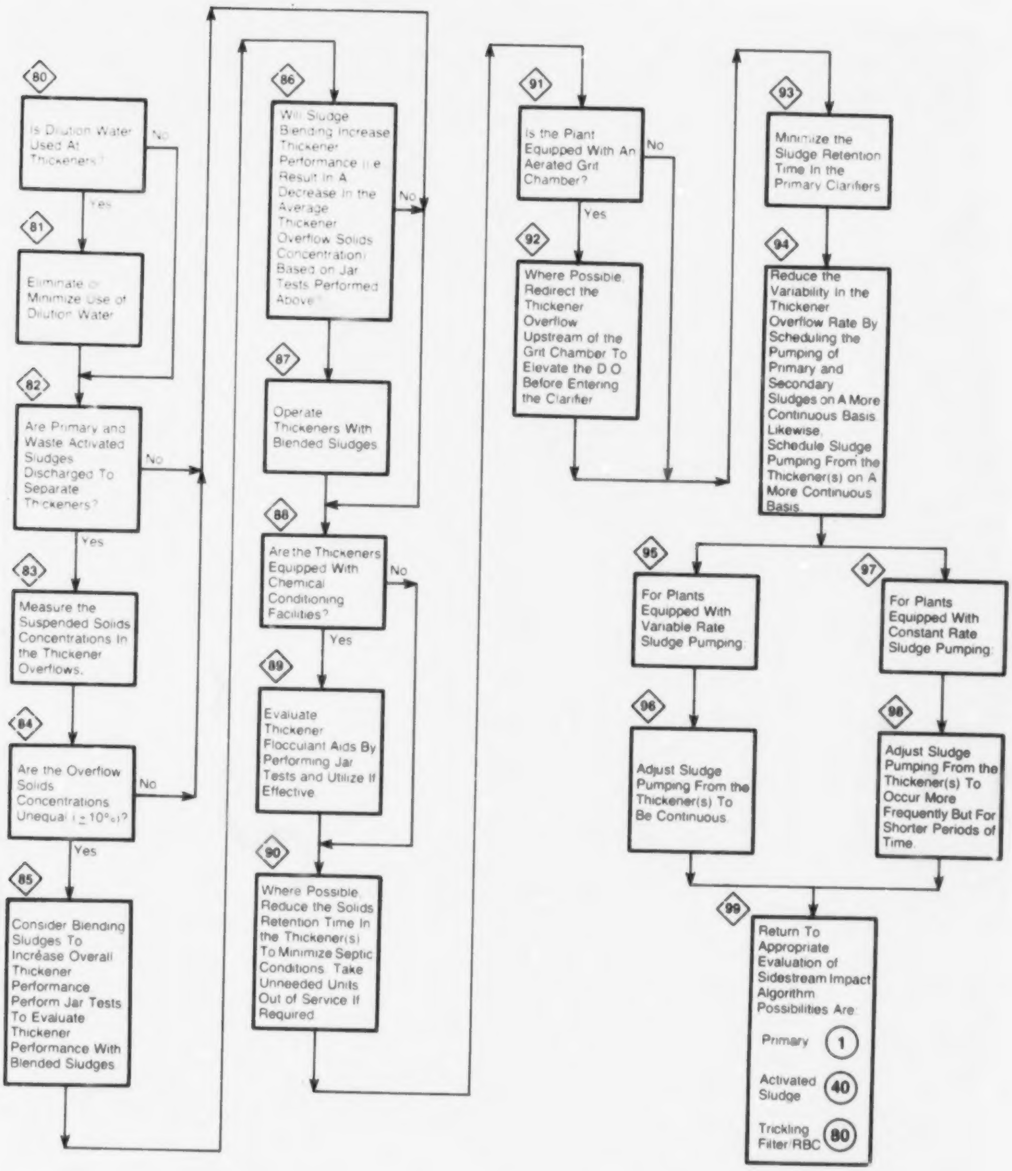

80
Is Dilution Water Used At Thickeners?
No
Yes
81
Eliminate or Minimize Use of Dilution Water
82
Are Primary and Waste Activated Sludges Discharged To Separate Thickeners?
No
Yes
83
Measure the Suspended Solids Concentrations In the Thickener Overflows.
84
Are the Overflow Solids Concentrations Unequal (±10%)?
No
Yes
85
Consider Blending Sludges To Increase Overall Thickener Performance Perform Jar Tests To Evaluate Thickener Performance With Blended Sludges
86
Will Sludge Blending Increase Thickener Performance (i.e. Result In A Decrease In the Average Thickener Overflow Solids Concentration) Based on Jar Tests Performed Above?
No
87
Operate Thickeners With Blended Sludges
88
Are the Thickeners Equipped With Chemical Conditioning Facilities?
No
Yes
89
Evaluate Thickener Flocculant Aids By Performing Jar Tests and Utilize If Effective
90
Where Possible, Reduce the Solids Retention Time In the Thickener(s) To Minimize Septic Conditions. Take Unneeded Units Out of Service If Required
91
Is the Plant Equipped With An Aerated Grit Chamber?
No
Yes
92
Where Possible, Redirect the Thickener Overflow Upstream of the Grit Chamber To Elevate the D.O. Before Entering the Clarifier
93
Minimize the Sludge Retention Time In the Primary Clarifiers
94
Reduce the Variability In the Thickener Overflow Rate By Scheduling the Pumping of Primary and Secondary Sludges on A More Continuous Basis. Likewise, Schedule Sludge Pumping From the Thickener(s) on A More Continuous Basis.
95
For Plants Equipped With Variable Rate Sludge Pumping:
96
Adjust Sludge Pumping From the Thickener(s) To Be Continuous.
97
For Plants Equipped With Constant Rate Sludge Pumping:
98
Adjust Sludge Pumping From the Thickener(s) To Occur More Frequently But For Shorter Periods of Time.
99
Return To Appropriate Evaluation of Sidestream Impact Algorithm. Possibilities Are:
Primary
1
Activated Sludge
40
Trickling Filter/RBC
80

Figure 11. Operational methods to reduce the impact of gravity thickener sidestreams on mainstream processes.

Flocculant Aids--

The thickener overflow (sidestream) often contains large amounts of "fines" that have escaped capture in the sludge thickening process. In order to limit the impact of the sidestream solids, plants so equipped should evaluate and utilize flocculant aids immediately preceding or in the sludge thickeners.

Detention Time--

Where possible, the sludge detention time in the thickeners should be minimized to reduce the opportunity for septicity. This requires removing unneeded units from service. Note that this helps to minimize (or eliminate) dilution water usage.

Sidestream Entry--

For plants equipped with aerated grit chambers, redirect the thickener sidestream (if possible) upstream of the aerated grit chamber to elevate the DO prior to entering the primary clarifier.

Pumping (Sludge Removal)--

Reduce the variability of pumping activities associated with the thickener operation to provide for a more uniform operation and to lessen the instantaneous impact caused by irregular pumping activities.

For plants equipped with constant rate sludge removal facilities:

1. Remove sludge from the primary clarifier(s) to the thickener(s) more frequently. Refer to the primary clarification algorithm in Section 3.

2. Adjust secondary sludge wasting to occur more frequently, but for a shorter period of time. Eliminate wasting mixed liquor and waste secondary sludge from the recycle stream (AS only). Refer to AS, TF, or RBC algorithm in Section 3.

3. Adjust sludge removal from the thickener to occur more frequently, i.e., limit the inventory of solids in the thickener(s).

For plants equipped with variable rate sludge removal facilities:

1. Adjust primary sludge removal to be as continuous as possible.

2. Adjust secondary sludge flow rate to be as continuous as possible. Eliminate wasting mixed liquor and waste secondary sludge from the recycle stream (AS only).

3. Adjust sludge removal from the thickener(s) to be as continuous as possible. Limit the inventory of solids in the thickeners.

The operational methods generally available for gravity thickeners to reduce the quality/impact of the sidestream have been presented in this subsection. Return to the appropriate mainstream evaluation algorithm to determine whether the impact has been reduced to an acceptable degree or if design modifications are required to achieve further reductions.

Dissolved Air Flotation Control of Sidestream Impact

Information contained in this section includes:

- Dissolved Air Flotation Control
- Discussion

The use of this algorithm is described in the User's Guide in Section 2 and an example is provided in Appendix B. Prior to the use of this algorithm, the user must develop and implement a Process Monitoring Program specific to the facility as is described in Section 2. The following algorithm is designed to apply to a large number of POTW's; therefore, it must be tailored to fit the user's requirements for the specific POTW.

The dissolved air flotation algorithm is presented in Figure 12.

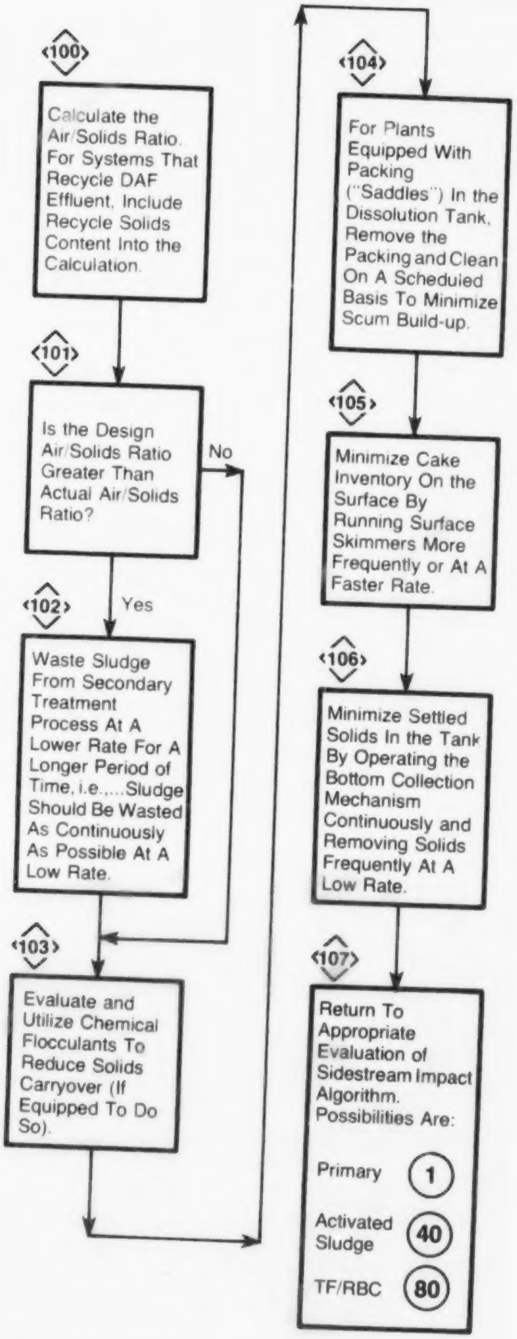
Loading--

Check the loading applied to each unit and determine the air/solids ratio. Remember to include the suspended solids concentration of the recycle stream.

If the actual air/solids ratio is less than the design ratio, the DAF unit is overloaded and may be incapable of treating the excess load. The sludge feed rate to the unit must be decreased. In order to keep up with plant sludge production and operate within design limits of the system, the sludge feed rate must be decreased and the operating time extended.

Flocculant Aids--

For plants equipped with chemical conditioning facilities, evaluate and utilize flocculant aids at the thickener to reduce solids carryover.



Calculate the Air/Solids Ratio. For Systems That Recycle DAF Effluent, Include Recycle Solids Content Into the Calculation.

Is the Design Air/Solids Ratio Greater Than Actual Air/Solids Ratio?

Waste Sludge From Secondary Treatment Process At A Lower Rate For A Longer Period of Time, i.e.,...Sludge Should Be Wasted As Continuously As Possible At A Low Rate.

Evaluate and Utilize Chemical Flocculants To Reduce Solids Carryover (If Equipped To Do So).

For Plants Equipped With Packing ("Saddles") In the Dissolution Tank, Remove the Packing and Clean On A Scheduled Basis To Minimize Scum Build-up.

Minimize Cake Inventory On the Surface By Running Surface Skimmers More Frequently or At A Faster Rate.

Minimize Settled Solids In the Tank By Operating the Bottom Collection Mechanism Continuously and Removing Solids Frequently At A Low Rate.

Return To Appropriate Evaluation of Sidestream Impact Algorithm. Possibilities Are:

Primary

Activated Sludge

TF/RBC

Figure 12. Operational methods to reduce the impact of dissolved air flotation sidestreams on mainstream processes.

Dissolution Tank--

Dissolved air flotation systems that have an effective detention time of one minute or less in the dissolution tank usually contain a packing material in the tank to enhance dissolution. The packing material may become coated with a scale and plug (especially if a recycle stream is used) which reduces dissolution. The packing material should therefore be periodically checked for scale and plugging, and cleaned as required.

Sludge Removal--

The sludge cake that is developed on the surface may become too thick and extend into the water surface ultimately to be carried out in the subnatant. In order to minimize this problem, the surface sludge cake should be kept to a reasonable thickness (approximately 3"). Where equipped to do so, adjust the top collection mechanism (ON-OFF or speed) to maintain approximately 3" or less of sludge cake.

A portion of the sludge that enters the dissolved air flotation unit will not float and subsequently settles to the bottom of the tank. This sludge, if left unattended, will become septic and eventually rise to be carried out in the tank overflow.

The bottom collection mechanism (if separate from the top mechanism) should be operated on a continuous basis, and settled sludge should be pumped from the sludge hopper once a day.

Anaerobic Digestion Control of Sidestream Impact

Information contained in this section includes:

- Anaerobic Digestion Control
- Discussion

The use of this algorithm is described in the User's Guide in Section 2 and an example is provided in Appendix B. Prior to the use of this algorithm, the user must develop and implement a Process Monitoring Program specific to the facility as is described in Section 2. The following algorithm is designed to apply to a large number of POTW's; therefore, it must be tailored to fit the user's requirements for the specific POTW.

The anaerobic digestion algorithm is presented in Figure 13.

Sludge Feed--

Schedule sludge pumping to the digester to occur on a more continuous basis to lessen the impact caused by irregular pumping activities.

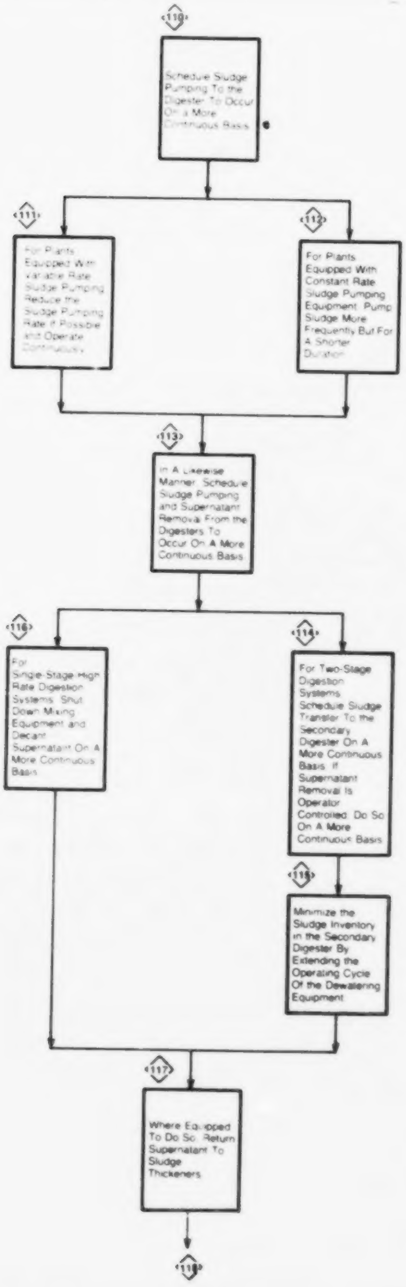

110
Schedule Sludge Pumping To the Digester To Occur On a More Continuous Basis
111
For Plants Equipped With Variable Rate Sludge Pumping Reduce the Sludge Pumping Rate if Possible and Operate Continuously
112
For Plants Equipped With Constant Rate Sludge Pumping Equipment, Pump Sludge More Frequently But For A Shorter Duration
113
In A Likewise Manner, Schedule Sludge Pumping and Supernatant Removal From the Digesters To Occur On A More Continuous Basis
116
For Single-Stage High Rate Digestion Systems, Shut Down Mixing Equipment and Decant Supernatant On A More Continuous Basis
114
For Two-Stage Digestion Systems Schedule Sludge Transfer To the Secondary Digester On A More Continuous Basis. If Supernatant Removal Is Operator Controlled, Do So On A More Continuous Basis
115
Minimize the Sludge Inventory in the Secondary Digester By Extending the Operating Cycle Of the Dewatering Equipment
117
Where Equipped To Do So, Return Supernatant To Sludge Thickeners
118

Figure 13. Operational methods to reduce the impact of anaerobic digester sidestreams on mainstream processes.

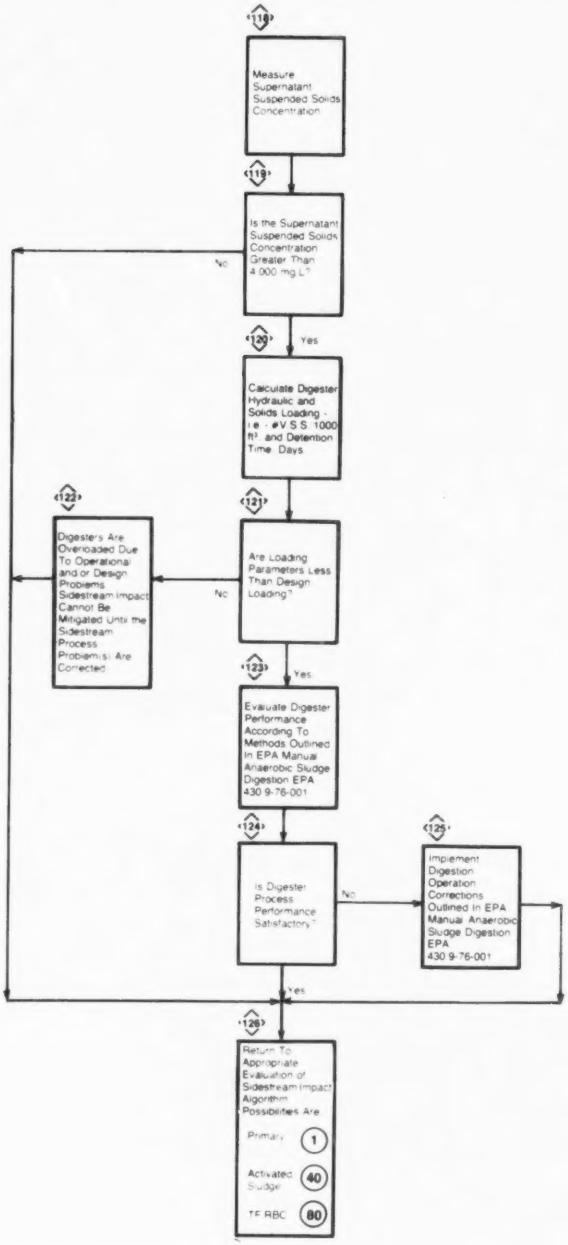

118
Measure Supernatant Suspended Solids Concentration
119
Is the Supernatant Suspended Solids Concentration Greater Than 4,000 mg/L?
No
Yes
120
Calculate Digester Hydraulic and Solids Loading - i.e. - #V.S.S./1000 ft³, and Detention Time, Days
121
Are Loading Parameters Less Than Design Loading?
No
122
Digesters Are Overloaded Due To Operational and/or Design Problems. Sidestream Impact Cannot Be Mitigated Until the Sidestream Process Problem(s) Are Corrected
Yes
123
Evaluate Digester Performance According To Methods Outlined In EPA Manual Anaerobic Sludge Digestion EPA 430/9-76-001
124
Is Digester Process Performance Satisfactory?
No
125
Implement Digestion Operation Corrections Outlined In EPA Manual Anaerobic Sludge Digestion EPA 430/9-76-001
Yes
126
Return To Appropriate Evaluation of Sidestream Impact Algorithm. Possibilities Are:
Primary
1
Activated Sludge
40
TF/RBC
80

Figure 13. (continued)

For plants equipped with constant rate sludge pumps, pump sludge more frequently but for a shorter duration. For plants equipped with variable rate sludge pumps, reduce the sludge pumping rate and operate continuously, if possible.

Note that the sludge mass to be transferred to the digester should be determined based on the operational loadings parameters.

Supernatant Removal--

Schedule sludge pumping and supernatant removal from the digester to occur on a more continuous basis.

For single-stage high rate digestion systems, shut down mixing equipment and decant supernatant on a more continuous basis. If supernatant removal is operator-controlled (i.e., not displaced by sludge pumping), do so on a more continuous basis.

Minimize the sludge inventory in the secondary digester by extending the operating cycle of the dewatering equipment. This will help to limit supernatant solids carry-over.

Supernatant removal should be frequent to minimize the impact of large sustained supernatant return flows on the mainstream treatment process. As an example, if three feet of digester supernatant is removed every three days, one foot of supernatant can be removed daily to "spread" the large impact that normally is created every third day.

Digester Loading--

Measure the supernatant suspended solids concentration. If it exceeds 4,000 mg/L check the conventional digester loading parameters (especially the organic and hydraulic loading conditions) and performance. The organic loading is typically expressed as pounds of volatile suspended solids (fed to the digester) per cubic foot of available digestion volume (lbs VSS/ft^3). The hydraulic loading (detention time) is expressed in days.

Compare the digester actual loading with the design loading and determine whether the system is being operated beyond the design limits.

If the system is being operated beyond design limits, the supernatant quality cannot be optimized until the operational and/or design conditions responsible for the overload conditions have been corrected.

Digester Performance--

If the system is operated within the design loading limits, the performance of the digestion process should be evaluated to determine the cause of the poor supernatant quality. Note that abnormal pH conditions, volatile acids/alkalinity ratio, temperature, heavy metal concentration, etc., can affect digester performance which will ultimately affect the sidestream (supernatant) quality. Factors which affect anaerobic digester performance and corrective measures are outlined in the EPA Manual on Anaerobic Sludge Digestion (No. EPA 430/9-76-001).

Aerobic Digestion Control of Sidestream Impact

Information contained in this section includes:

- Aerobic Digestion Control
- Discussion

The use of this algorithm is described in the User's Guide in Section 2 and an example is provided in Appendix B. Prior to the use of this algorithm, the user must develop and implement a Process Monitoring Program specific to the facility as is described in Section 2. The following algorithm is designed to apply to a large number of POTW's; therefore, it must be tailored to fit the user's requirements for the specific POTW.

The aerobic digestion algorithm is presented in Figure 14.

The sidestream (supernatant liquid) from the aerobic digestion process does not contain high concentrations of soluble organics. Therefore, the impacts are related primarily to the volume of supernatant and the suspended solids concentration.

Supernatant Removal--

Allow the digested sludge to settle properly before removing supernatant. The required settling time can be estimated by performing a laboratory settling test. The aeration/mixing equipment should be then turned off for the minimum period indicated by the settling test before supernatant is removed.

Supernatant removal should be frequent to minimize the impact of large, sustained supernatant return flows on the mainstream treatment process. As an example, if three feet of digester supernatant is removed every three days, one foot of supernatant can be removed daily to "spread" the large impact that normally is created every third day.

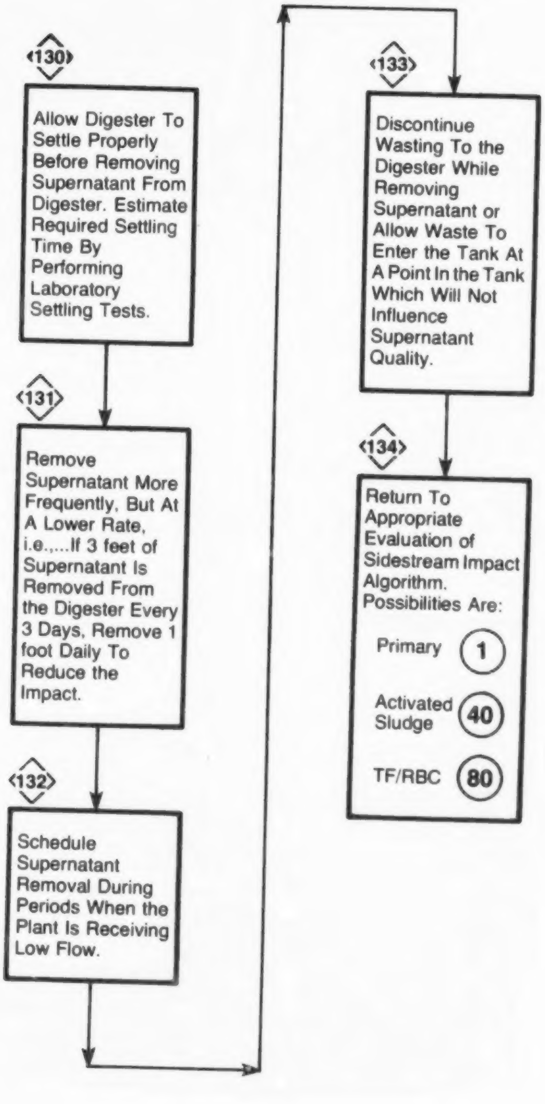

130
Allow Digester To Settle Properly Before Removing Supernatant From Digester. Estimate Required Settling Time By Performing Laboratory Settling Tests.
131
Remove Supernatant More Frequently, But At A Lower Rate, i.e.,...If 3 feet of Supernatant Is Removed From the Digester Every 3 Days, Remove 1 foot Daily To Reduce the Impact.
132
Schedule Supernatant Removal During Periods When the Plant Is Receiving Low Flow.
133
Discontinue Wasting To the Digester While Removing Supernatant or Allow Waste To Enter the Tank At A Point In the Tank Which Will Not Influence Supernatant Quality.
134
Return To Appropriate Evaluation of Sidestream Impact Algorithm. Possibilities Are:
Primary
1
Activated Sludge
40
TF/RBC
80

Figure 14. Operational methods to reduce the impact of aerobic digestion sidestreams on mainstream processes.

If the normal practice is to waste sludge to the digester while supernatant is being removed, this practice should be discontinued. This will prevent disturbance and degradation of the supernatant quality while it is being removed. If it is not possible to discontinue wasting during supernatant removal, the supernatant removal point and the sludge feed point should be located in such a manner that the supernatant quality is not affected.

Vacuum Filtration Control of Sidestream Impact

Information contained in this section includes:

- Vacuum Filtration Control
- Discussion

The use of this algorithm is described in the User's Guide in Section 2 and an example is provided in Appendix B. Prior to the use of this algorithm, the user must develop and implement a Process Monitoring Program specific to the facility as is described in Section 2. The following algorithm is designed to apply to a large number of POTW's; therefore, it must be tailored to fit the user's requirements for the specific POTW.

The vacuum filtration algorithm is presented in Figure 15.

Planned Shutdown--

Shutdown of the vacuum filtration equipment should be a scheduled activity and should be scheduled so that "day tanks" and filter vats are at their lowest levels before the equipment is shut down. This would eliminate the necessity of dumping the full vat and tank contents before the equipment is cleaned.

Where equipped to do so, the remaining vat and tank contents that must be discarded should be returned to the sludge thickeners and not directly back to the main processes. Note that if excess conditioning chemicals are discarded, it usually benefits the sludge thickener operation.

Cleaning--

Each vacuum filter should be cleaned after use. Cleaning of the filters cannot be over-emphasized. The performance of vacuum filters and the quality of the sidestream (filtrate) often is directly related to equipment clean-up.

For those systems that require the filters to operate continuously for long periods of time, provisions should be made to allow each filter to be taken out of service for a period of time for clean-up. The time interval between clean-up will vary

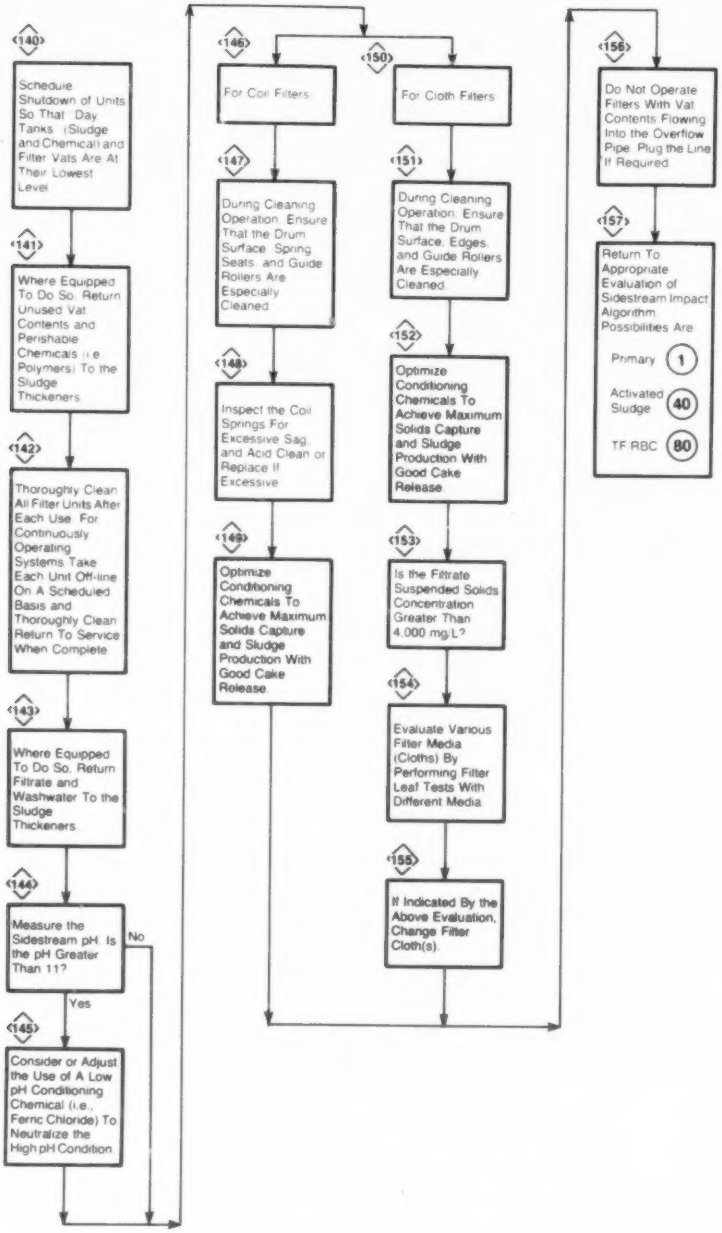

140
Schedule Shutdown of Units So That Day Tanks (Sludge and Chemical) and Filter Vats Are At Their Lowest Level
141
Where Equipped To Do So, Return Unused Vat Contents and Perishable Chemicals (i.e. Polymers) To the Sludge Thickeners
142
Thoroughly Clean All Filter Units After Each Use. For Continuously Operating Systems Take Each Unit Off-line On A Scheduled Basis and Thoroughly Clean. Return To Service When Complete
143
Where Equipped To Do So, Return Filtrate and Washwater To the Sludge Thickeners
144
Measure the Sidestream pH. Is the pH Greater Than 11?
No
Yes
145
Consider or Adjust the Use of A Low pH Conditioning Chemical (i.e., Ferric Chloride) To Neutralize the High pH Condition
146
For Coil Filters
147
During Cleaning Operation, Ensure That the Drum Surface, Spring Seats, and Guide Rollers Are Especially Cleaned
148
Inspect the Coil Springs For Excessive Sag and Acid Clean or Replace If Excessive
149
Optimize Conditioning Chemicals To Achieve Maximum Solids Capture and Sludge Production With Good Cake Release
150
For Cloth Filters
151
During Cleaning Operation, Ensure That the Drum Surface, Edges, and Guide Rollers Are Especially Cleaned
152
Optimize Conditioning Chemicals To Achieve Maximum Solids Capture and Sludge Production With Good Cake Release
153
Is the Filtrate Suspended Solids Concentration Greater Than 4,000 mg/L?
154
Evaluate Various Filter Media (Cloths) By Performing Filter Leaf Tests With Different Media
155
If Indicated By the Above Evaluation, Change Filter Cloth(s)
156
Do Not Operate Filters With Vat Contents Flowing Into the Overflow Pipe. Plug the Line If Required
157
Return To Appropriate Evaluation of Sidestream Impact Algorithm. Possibilities Are
Primary 1
Activated Sludge 40
TF RBC 80

Figure 15. Operational methods to reduce the impact of vacuum filter sidestreams on mainstream processes.

for each facility; however, for plants with a high rag content in their sludge, the interval may be 24 hours or less.

The time interval between clean-up for continuously operating filters can be determined by monitoring the filtrate quality. The filtrate quality should be at its best after cleaning and degrade over time as the machine accumulates rags and debris. Once the average filtrate quality is exceeded, the machine should be scheduled for cleaning.

Filtrate Return--
When equipped to do so, the filtrate and the wash water from the spray systems should be returned to the sludge thickeners. This would prevent immediately impacting the main treatment process.

pH--
Many plants use sludge conditioning agents that affect the sidestream pH. These conditioning agents may include: lime, ferric chloride, ferric sulfate, aluminum chloride, etc. Once the existence of an impact has been determined, the user should take measures to neutralize the sidestream.

This may be accomplished by using or adjusting the dosage of a complementary conditioning agent to change the sidestream pH. As an example, a given plant may be using lime only as a conditioning agent and by using the evaluation algorithm, the user has determined that the high pH of the sidestream is impacting adversely on the mainstream treatment process. Since the pH of the sidestream is high, the user should select a complementary conditioning agent, i.e., one with a low pH, such as ferric chloride to use in conjunction with lime to result in a sidestream with a more neutral pH.

Filter Operation--
For coil vacuum filters--During clean-up of the filter, special attention should be paid to ensure that the drum surface, spring seats, and rollers are thoroughly cleaned. Rag or sludge build-ups in these locations can cause gaps or misalignment of the springs which allows sludge to be drawn directly from the filter vat and into the filtrate.

In addition, rags wedged between springs can cause the same condition and should be completely removed during clean-up. During normal operation, the filter should be examined for excessive rag build-up, and taken off-line and cleaned as required.

The coil springs should be examined periodically for excessive "sag" and corrected if required. Springs that are stretched and sagging do not seal properly and allow sludge to be drawn between the gaps and into the filtrate.

Spring stretching is most prevalent in plants that use lime as a conditioning chemical. This is due to the build-up lime scale between individual coils of each spring thus stretching the spring. Lime scale can be removed by acid cleaning the filter (as recommended by the manufacturer).

In the event that acid cleaning does not reduce spring stretch, replace the springs.

Optimize the use and dosage of conditioning chemicals to achieve maximum solids capture while maintaining good sludge production (high solids content) and cake release.

The conditioning dosage can be optimized on a laboratory scale by performing Buchner funnel and/or filter leaf tests.

For treatment plants that use polymer(s) as a conditioning agent, special attention must be paid to polymer dosage and floc development. Development of an acceptable floc for dewatering is not only a function of the conditioning chemical dosage, but is also a function of the operation of the conditioning/mixing tank. Once the optimum conditioning dosage has been determined, the detention time through the conditioning tank should be varied to achieve a stable, well formed floc.

For cloth vacuum filters--During clean-up of the filter, special attention should be paid to ensure that the drum surface, drum edges, and guide rollers are thoroughly cleaned.

The cleanliness of the drum surface and guide rollers will impact more on the vacuum filter output than it will on filtrate quality. However, severe rag and sludge accumulations will cause creases and misalignments of the cloth which may allow sludge to be drawn directly into the filtrate.

The cleanliness of the drum edges is important in achieving an acceptable filtrate quality. The filter cloth in many cases actually seals along the edges of the filter drum. Rag and sludge build-ups along the edges prevent proper sealing of the cloth and allows sludge to be drawn directly into the filtrate when rotated through the vat. Some operators have found success in keeping these edges relatively clean by directing low pressure/low volume sprays directly at the edges of the drum. The sprays are directed to the place where the cloth leaves the drum toward the discharge rollers.

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Optimize chemical conditioning as described for coil filters.

Analyze the filtrate stream for suspended solids content. If the suspended solids content exceeds 4,000 mg/L, proceed as follows:

1. Evaluate various filter cloths to reduce the filtrate suspended solids concentration (increase solids capture), while not adversely affecting filter yield. The different types of media can be evaluated by performing filter leaf tests. Note that the evaluations should be based on filter yield and solids capture (filtrate quality).
2. If, based on the above evaluation, a different filter media is recommended, replace the media. Note that for plants with multiple cloth filters, it may be advisable to replace the media on one unit and compare its performance with the remaining units. If the media compares favorably (i.e., increases capture and maintains yield), replace the media on all units. Do not discard old media. Future sludge and/or conditioning changes may require exchanging media.

For coil and cloth vacuum filters--Do not operate filters with the vat contents flowing into the overflow. This sludge passes directly into the filter drain and can become a major sidestream. The feed (sludge and conditioning chemicals) should be controlled at all times to prevent sludge discharge through the overflow line. If required, plug the overflow.

Centrifuge Control of Sidestream Impact

Information contained in this section includes:

- Centrifuge Control
- Discussion

The use of this algorithm is described in the User's Guide in Section 2 and an example is provided in Appendix B. Prior to the use of this algorithm, the user must develop and implement a Process Monitoring Program specific to the facility as is described in Section 2. The following algorithm is designed to apply to a large number of POTW's; therefore, it must be tailored to fit the user's requirements for the specific POTW.

The centrifuge algorithm is presented in Figure 16.

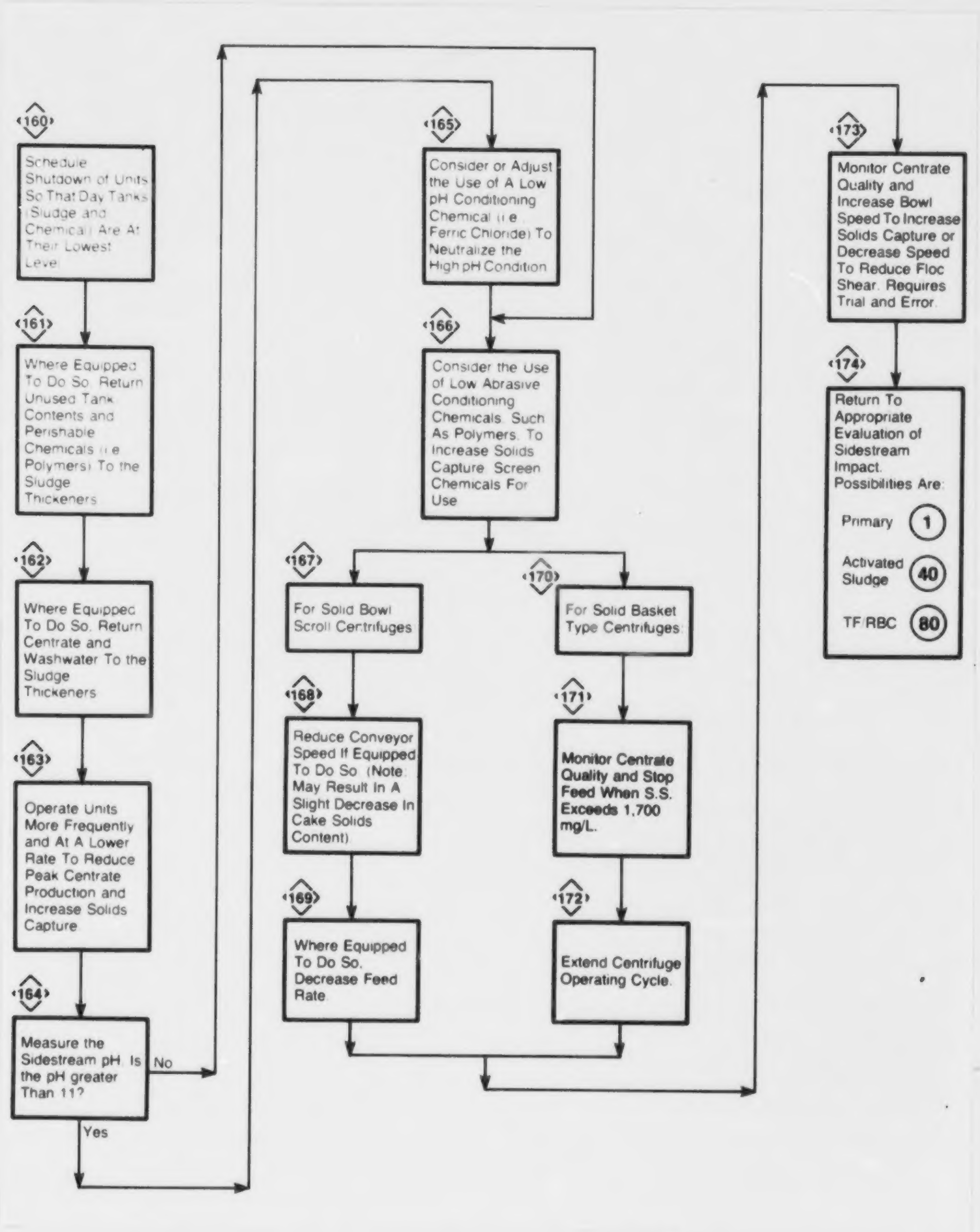
160
Schedule Shutdown of Units So That Day Tanks (Sludge and Chemical) Are At Their Lowest Level
161
Where Equipped To Do So, Return Unused Tank Contents and Perishable Chemicals (i.e. Polymers) To the Sludge Thickeners
162
Where Equipped To Do So, Return Centrate and Washwater To the Sludge Thickeners
163
Operate Units More Frequently and At A Lower Rate To Reduce Peak Centrate Production and Increase Solids Capture
164
Measure the Sidestream pH. Is the pH greater Than 11?
No
Yes
165
Consider or Adjust the Use of A Low pH Conditioning Chemical (i.e. Ferric Chloride) To Neutralize the High pH Condition
166
Consider the Use of Low Abrasive Conditioning Chemicals, Such As Polymers, To Increase Solids Capture. Screen Chemicals For Use
167
For Solid Bowl Scroll Centrifuges
168
Reduce Conveyor Speed If Equipped To Do So. (Note: May Result In A Slight Decrease In Cake Solids Content)
169
Where Equipped To Do So, Decrease Feed Rate
170
For Solid Basket Type Centrifuges
171
Monitor Centrate Quality and Stop Feed When S.S. Exceeds 1,700 mg/L.
172
Extend Centrifuge Operating Cycle.
173
Monitor Centrate Quality and Increase Bowl Speed To Increase Solids Capture or Decrease Speed To Reduce Floc Shear. Requires Trial and Error.
174
Return To Appropriate Evaluation of Sidestream Impact. Possibilities Are:
Primary
1
Activated Sludge
40
TF/RBC
80

Figure 16. Operational methods to reduce the impact of centrifuge sidestreams on mainstream processes.

Planned Shutdown--

As with vacuum filtration, the shutdown of the centrifuge equipment should be a scheduled activity. The shutdown should be scheduled so that the "day tanks" (sludge and chemical) are at their lowest level before the equipment is shut down. This prevents the necessity of dumping the full tank contents before the equipment is cleaned.

Where equipped to do so, the remaining vat and tank contents that must be discarded should be returned to the sludge thickeners and not directly back to the main processes. Note that if some excess conditioning chemicals are discarded, they usually benefit the sludge thickener operation.

Centrate Return--

If equipped to do so, return centrate and wash water to the sludge thickeners. This prevents immediately impacting the treatment process.

Detention Time--

Operate units more frequently and at a lower feed rate to reduce peak centrate production and to increase solids capture.

For solid bowl scroll centrifuges--Reduce the conveyor (scroll) speed if equipped to do so. This may result in a slight decrease in cake solids throughput.

Decrease the feed rate to the unit, where equipped to do so. This increases the detention time in the unit thus theoretically increasing solids capture.

For solid basket-type centrifuges--Monitor centrate quality and stop feed when the suspended solids concentration exceeds 1,700 mg/L. Continue to operate the unit for the duration of the cycle.

As a practical matter, the centrate stream cannot always be continuously monitored (unless equipped with a suspended solids analyzer) and used to make daily decisions. However, a correlation can be developed between feed duration and supernatant quality. A number of grab samples can be taken of the centrate at five to ten minute intervals while the unit is receiving feed. The samples should be analyzed for suspended solids, and results plotted vs. time. The operator can, by referring to the plot, select a feed cycle that will optimize centrate quality. This procedure should be repeated if the centrate suspended solids concentrations changes significantly.

Extend the centrifuge operating cycle. The portion of time varied should be the portion of the centrifuge cycle that the unit is not receiving feed sludge. The feed time (duration) is optimized above.

pH--

Many plants use sludge conditioning chemicals that affect the sidestream pH. Once the pH is found to have an impact, the user should take measures to neutralize the sidestream. This may be accomplished by using or adjusting the dosage of a second conditioning agent to change the sidestream pH. As an example, a given plant may be using lime only as a conditioning agent and, by using the evaluation algorithm, the user has determined that the high pH of the sidestream is impacting adversely on the mainstream treatment process. Since the pH of the sidestream is high, the user should select a complementary conditioning agent, i.e., one with low pH, such as ferric chloride, to use in conjunction with lime to result in a sidestream with a more neutral pH.

Speed--

Monitor centrate quality and increase the bowl speed to increase solids capture or decrease speed to reduce floc shear.

The operating speed of the unit can affect the quality of the centrate by either being too low to separate the fine, lighter solids, or being too high, resulting in floc shear.

Trial and error speed changes can be made (on those units so equipped) in order to evaluate the impact on centrate quality. As a starting point, if settling and flocculation tests indicate a good floc formation with observed low supernatant solids, begin reducing the centrifuge speed and monitor the centrate suspended solids concentration. If the centrate quality improves at the reduced speed (given adequate time for the change to take effect), continue to reduce the speed of the unit until no additional improvement is noted. Take the opposite course of action, i.e., increase speed, if the intent is to separate "fines" that occur in the centrate.

The operational methods generally available for centrifuges to reduce the quality/impact of the sidestream have been presented in this subsection. Return to the appropriate mainstream evaluation algorithm to determine whether the impact has been reduced to an acceptable degree or if design modifications are required to achieve further reductions.

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Belt Filter Control of Sidestream Impact

Information contained in this section includes:

- Belt Filter Control
- Discussion

The use of this algorithm is described in the User's Guide in Section 2 and an example is provided in Appendix B. Prior to the use of this algorithm, the user must develop and implement a Process Monitoring Program specific to the facility as is described in Section 2. The following algorithm is designed to apply to a large number of POTW's; therefore, it must be tailored to fit the user's requirements for the specific POTW.

The belt filter algorithm is presented in Figure 17.

Planned Shutdown--

As for vacuum filters and centrifuges, the shutdown of the belt filter equipment should be a scheduled activity. The shutdown should be scheduled so that the "day tanks" are at their lowest levels before the equipment is shut down. This prevents the necessity of dumping the full tank contents before the equipment is cleaned.

Where equipped to do so, the remaining tank contents that must be discarded should be returned to the sludge thickeners and not directly back to the treatment process. Note that if some excess conditioning chemicals are discarded, they usually benefit the sludge thickener operation.

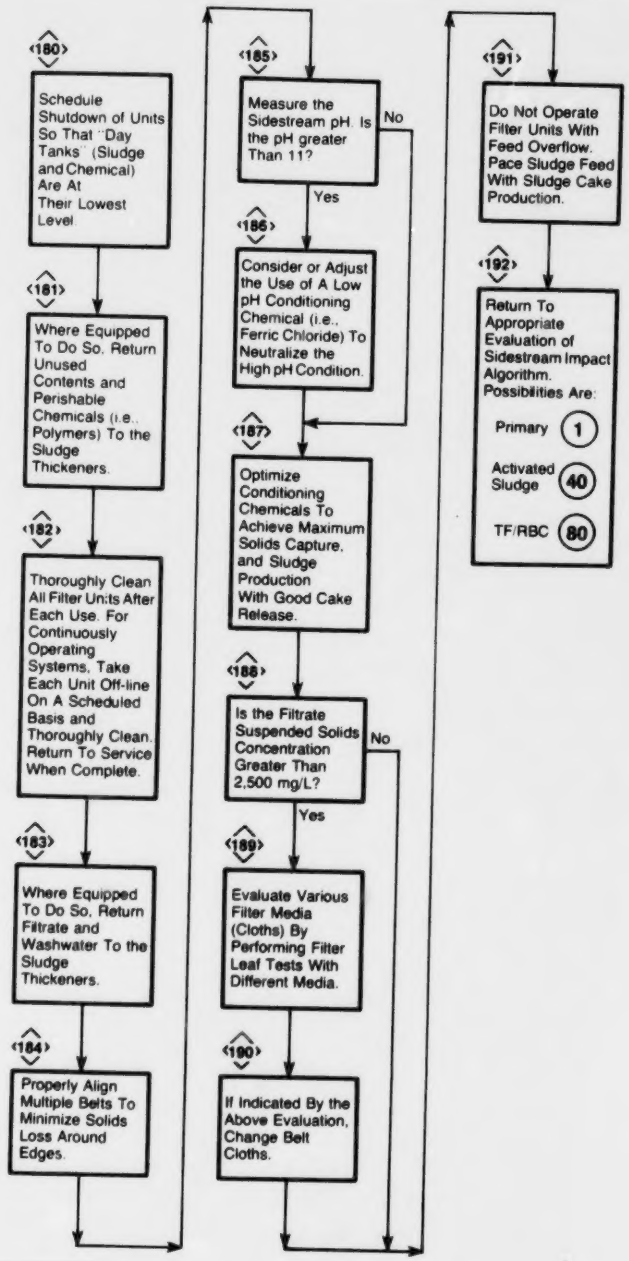
Cleaning--

Each belt filter should be cleaned after each use. For those systems that require the filters to operate continuously for long periods of time, provisions should be made to allow each filter to be taken out of service for a period of time for clean-up.

Special attention should be placed on maintaining clean guide and compression rollers. Sludge "fines" which pass through media will build up on the rollers and, if not cleaned periodically, will cause belt misalignment and may degrade filtrate quality.

Filtrate Return--

When equipped to do so, the filtration and the wash water from the spray systems should be returned to the sludge thickeners. This prevents immediately impacting the main treatment process.


180
Schedule Shutdown of Units So That "Day Tanks" (Sludge and Chemical) Are At Their Lowest Level.
181
Where Equipped To Do So, Return Unused Contents and Perishable Chemicals (i.e., Polymers) To the Sludge Thickeners.
182
Thoroughly Clean All Filter Units After Each Use. For Continuously Operating Systems, Take Each Unit Off-line On A Scheduled Basis and Thoroughly Clean. Return To Service When Complete.
183
Where Equipped To Do So, Return Filtrate and Washwater To the Sludge Thickeners.
184
Properly Align Multiple Belts To Minimize Solids Loss Around Edges.
185
Measure the Sidestream pH. Is the pH greater Than 11?
No
Yes
186
Consider or Adjust the Use of A Low pH Conditioning Chemical (i.e., Ferric Chloride) To Neutralize the High pH Condition.
187
Optimize Conditioning Chemicals To Achieve Maximum Solids Capture, and Sludge Production With Good Cake Release.
188
Is the Filtrate Suspended Solids Concentration Greater Than 2,500 mg/L?
No
Yes
189
Evaluate Various Filter Media (Cloths) By Performing Filter Leaf Tests With Different Media.
190
If Indicated By the Above Evaluation, Change Belt Cloths.
191
Do Not Operate Filter Units With Feed Overflow. Pace Sludge Feed With Sludge Cake Production.
192
Return To Appropriate Evaluation of Sidestream Impact Algorithm. Possibilities Are:
Primary 1
Activated Sludge 40
TF/RBC 80

17

Figure 17. Operational methods to reduce the impact of belt filter sidestreams on mainstream processes.

BF

pH--

Many plants use sludge conditioning agents that affect the sidestream pH. These conditioning agents include lime, ferric chloride, ferrous sulfate, aluminum chloride, etc. Once the existence of an impact has been determined, the user should take measures to neutralize the sidestream. This may be accomplished by using or adjusting the dosage of a secondary conditioning agent to change the sidestream pH. As an example, a given plant may be using lime only as a conditioning agent and, by using the evaluation algorithm, the user has determined that the high pH of the sidestream is impacting adversely on the mainstream. Since the pH of the sidestream is high, the user should select a secondary conditioning agent, such as ferric chloride, to use in conjunction with lime to result in a sidestream with a more neutral pH.

Chemical Conditioning--

Optimize the use and dosage of conditioning chemicals to achieve maximum solids capture while maintaining good sludge production (high solids content) and cake release.

The conditioning dosage can be optimized on a laboratory scale by performing Buchner funnel and/or filter leaf tests.

For treatment plants that use polymer(s) as a conditioning agent, special attention must not only be paid to the polymer dosage but also to floc development. Development of an acceptable floc for dewatering is not only a function of the conditioning chemical dosage, but is also a function of the operation of the conditioning/mixing tank (if provided). Once the optimum conditioning dosage has been determined, the detention time through the conditioning tank should be varied to achieve a stable well formed floc.

Filter Cloth--

Analyze the filtrate stream for suspended solids content. If the suspended solids content exceeds 2,500 mg/L, proceed as follows:

1. Evaluate various filter cloths to reduce the filtrate suspended solids concentration (increase solids capture) while not adversely affecting filter yield. The different types of media can be evaluated by performing filter leaf tests. Note that the evaluations should be based on filter yield and solids capture (filtrate quality).

2. If, based on the above evaluation, a different filter media is recommended replace the media. Note that for plants with multiple belt filters, it may be advisable to replace the media on one

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unit and compare its performance with the remaining units. If the media compares favorably (i.e., increases capture and maintains yield) replace the media on all units. Do not discard old media. Future sludge and/or conditioning changes may require exchanging media.

Sludge Feed Rate--

Do not overflow the sludge feed to the unit. The sludge feed should be paced with the sludge production of the unit by keeping discharged sludge within the form zone of the belt. Excessive feed rates may cause sludge to overflow the belt and pass directly into the filtrate.

The operational methods generally available in belt filters to reduce the quality/impact of the sidestream impact have been presented in this subsection. Return to the appropriate evaluation algorithm to determine whether the impact has been reduced or an acceptable degree to if design modifications are required to achieve further reductions.

Sand Bed Control of Sidestream Impact

Information contained in this section includes:

- Sand Bed Control
- Discussion

The use of this algorithm is described in the User's Guide in Section 2 and an example is provided in Appendix B. Prior to the use of this algorithm, the user must develop and implement a Process Monitoring Program specific to the facility as is described in Section 2. The following algorithm is designed to apply to a large number of POTW's; therefore, it must be tailored to fit the user's requirements for the specific POTW.

The sand drying bed algorithm is presented in Figure 18.

Sand drying beds are usually operated on a batch basis, i.e., sludge is introduced into a bed to a level of approximately 12 inches, flow is stopped, and the bed is isolated. The sludge is dewatered by a combination of filtration and evaporation.

Since the operation is usually batch, a sidestream (filtrate) peak occurs shortly after the bed is charged and trails off after a period of time (eight to 24 hours). The operator

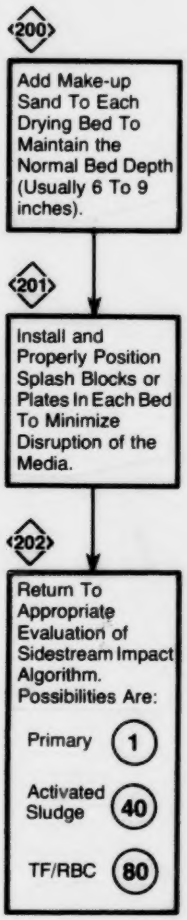
200
Add Make-up Sand To Each Drying Bed To Maintain the Normal Bed Depth (Usually 6 To 9 inches).
201
Install and Properly Position Splash Blocks or Plates In Each Bed To Minimize Disruption of the Media.
202
Return To Appropriate Evaluation of Sidestream Impact Algorithm. Possibilities Are:
Primary
1
Activated Sludge
40
TF/RBC
80

Figure 18. Operational methods to reduce the impact of sand drying bed sidestreams on mainstream processes.

generally has little or no control over the frequency and duration of the sidestream, therefore no operational methods to control the hydraulic impact of this sidestream are cited. However, the operator does have limited control over the filtrate quality. Refer to the following items.

Sand Depth--
The sand layer depth must be maintained at the original design depth (usually six to nine inches). Note that some sand is usually lost when sludge is removed from the bed. This sand should be replaced after each cleaning.

If the sand layer is depreciated sufficiently (to about three to four inches), sludge can "break through" the filter media and degrade the quality of the filtrate.

Splash Blocks/Plates--
Install and properly position splash blocks or plates in each filter bed. The splash blocks/plates aid in the prevention of bed erosion that is caused by sludge falling directly onto the filter media. Any noted erosion should be corrected by raking, and adding or repositioning splash blocks before a bed is used.

Note that an eroded portion of the bed may allow sludge to break through, as mentioned above, thus degrading the quality of the filtrate.

The operational methods generally available in sand drying beds to reduce the quality/impact of the sidestream have been presented in this subsection. Return to the appropriate evaluation algorithm to determine whether the impact was reduced to an acceptable degree or if design modifications are required to achieve further reductions.

Sludge Lagoons Control of Sidestream Impact

Information contained in this section includes:

- Sludge Lagoon Control
- Discussion

The use of this algorithm is described in the User's Guide in Section 2 and an example is provided in Appendix B. Prior to the use of this algorithm, the user must develop and implement a Process Monitoring Program specific to the facility as is described in Section 2. The following algorithm is designed to apply to a large number of POTW's; therefore, it must be tailored to fit the user's requirements for the specific POTW.

The sludge lagoon algorithm is presented in Figure 19.

Allow adequate settling time before removing supernatant from the lagoon. Usually, four to eight hours settling time should be sufficient; however, actual time can be estimated by performing laboratory settling tests.

Supernatant should be removed frequently to limit the impact of large sustained supernatant flows. As an example, if three feet of digester supernatant is removed every three days, one foot of supernatant can be removed each day to "spread" the large impact that would normally be created every third day.

If the normal practice is to waste sludge to the lagoon while the supernatant is being removed, this should be discontinued. This will prevent the disturbance of the settled solids and subsequent degradation of the supernatant quality while it is being removed. If it is not possible to discontinue wasting during supernatant removal, the supernatant should be removed or the waste introduced at points in the lagoon which will not cause degradation of supernatant quality.

The operational methods generally available in sludge lagoons to reduce the quality/impact of the sidestream have been presented in this subsection. Return to the appropriate mainstream evaluation algorithm to determine whether the impact has been reduced to an acceptable degree or if design modifications are required to achieve further reductons.

Heat Treatment/Wet Air Oxidation Control of Sidestream Impact

Information contained in this section includes:

- HT/WAO Control
- Discussion

The use of this algorithm is described in the User's Guide in Section 2 and an example is provided in Appendix B. Prior to the use of this algorithm, the user must develop and implement a Process Monitoring Program specific to the facility as is described in Section 2. The following algorithm is designed to apply to a large number of POTW's; therefore, it must be tailored to fit the user's requirements for the specific POTW.

The heat treatment/wet air oxidation algorithm is presented in Figure 20.

Operational Methods to Control Impacts--

Heat treatment and wet air oxidation are similar processes,

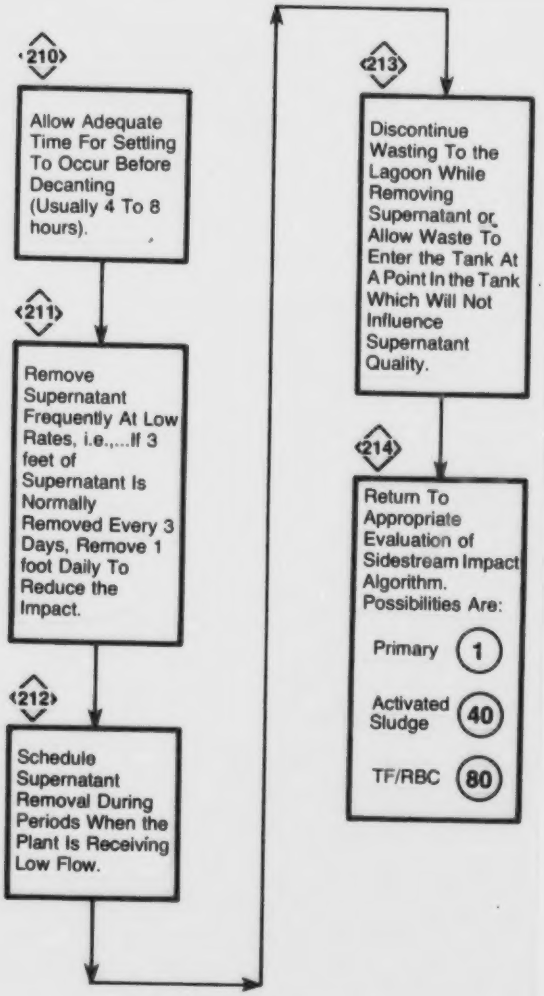
210
Allow Adequate Time For Settling To Occur Before Decanting (Usually 4 To 8 hours).
211
Remove Supernatant Frequently At Low Rates, i.e.,...If 3 feet of Supernatant Is Normally Removed Every 3 Days, Remove 1 foot Daily To Reduce the Impact.
212
Schedule Supernatant Removal During Periods When the Plant Is Receiving Low Flow.
213
Discontinue Wasting To the Lagoon While Removing Supernatant or Allow Waste To Enter the Tank At A Point In the Tank Which Will Not Influence Supernatant Quality.
214
Return To Appropriate Evaluation of Sidestream Impact Algorithm. Possibilities Are:
Primary 1
Activated Sludge 40
TF/RBC 80

Figure 19. Operational methods to reduce the impact of sludge lagoon sidestreams on mainstream processes.

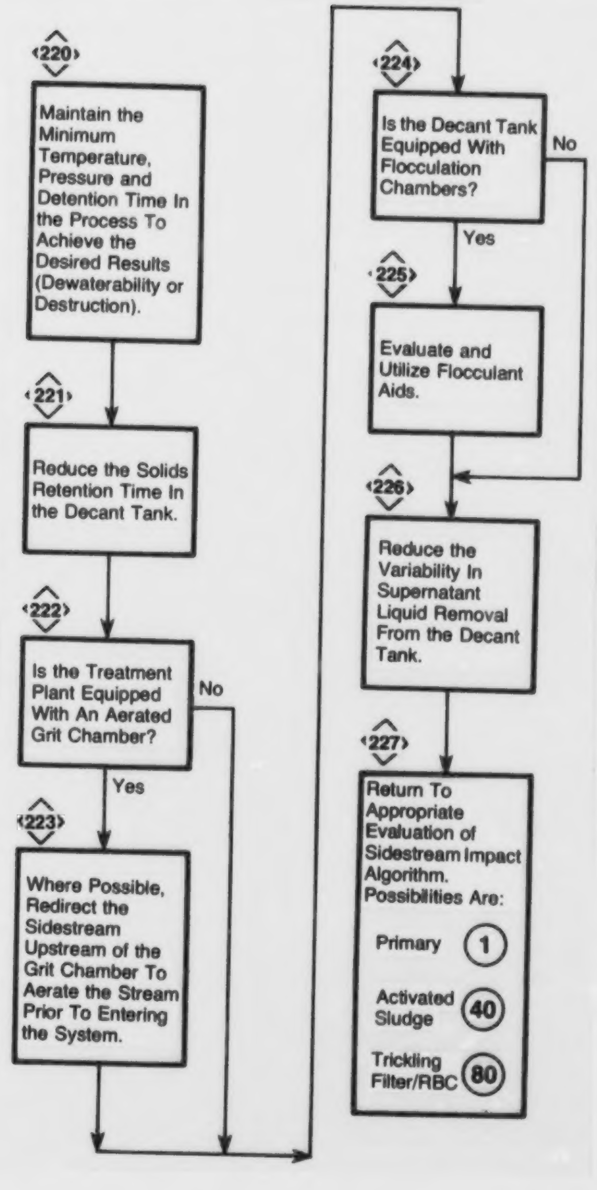
220
Maintain the Minimum Temperature, Pressure and Detention Time In the Process To Achieve the Desired Results (Dewaterability or Destruction).
221
Reduce the Solids Retention Time In the Decant Tank.
222
Is the Treatment Plant Equipped With An Aerated Grit Chamber?
No
Yes
223
Where Possible, Redirect the Sidestream Upstream of the Grit Chamber To Aerate the Stream Prior To Entering the System.
224
Is the Decant Tank Equipped With Flocculation Chambers?
No
Yes
225
Evaluate and Utilize Flocculant Aids.
226
Reduce the Variability In Supernatant Liquid Removal From the Decant Tank.
227
Return To Appropriate Evaluation of Sidestream Impact Algorithm. Possibilities Are:
Primary
1
Activated Sludge
40
Trickling Filter/RBC
80

Figure 20. Operational methods to reduce the impact of heat treatment and wet air oxidation sidestreams on mainstream processes.

differing mainly in the degree of treatment. The sidestreams generated from each process are similar, again differing by the degree of contamination (e.g., solubilization of solids).

Assuming that the operation is satisfactory as a process, the operator has little control over the sidestream quality. Abnormal operating practices (as noted below) can affect sidestream quality. However, the sidestream quality can be optimized (to some extent) during solids separation.

This algorithm assumes the use of a decant tank associated with the heat treatment/wet air oxidation process. For this document, this tank is considered the point of origin for the HT/WAO sidestream and is followed in the treatment scheme by some type of dewatering (e.g., VF, SB, LA, etc.). It is possible to take sludges processed by HT/WAO directly to vacuum filtration, centrifugation, belt filters, sand beds, sludge lagoons, etc. In the event that one of these options is used in conjunction with the HT/WAO process, the user should refer to the algorithm in this section dealing with that particular process.

HT/WAO Process Control--

Maintain the minimum temperature, pressure and detention time in the process to achieve the desired results (dewaterability or destruction).

Excessive temperatures and/or pressures help to produce fine solids that are difficult to remove and which enter into the sidestream. Operation below the recommended temperatures and pressures will improve the sidestream quality at the expense of the process.

Detention Time--

Reduce the solids detention time in the decant tank. This is accomplished by discharging the treated sludge to the sludge dewatering equipment (vacuum filters, sand beds, etc.) on a continuous basis (or as continuously as possible).

Sidestream Return--

For plants equipped with aerated girt chambers, redirect the HT/WAO sidestream (if possible) upstream of the aerated grit chamber to aerate the stream prior to entering the system.

Flocculant Aids--

The decanted liquid (sidestream) often contains large amounts of "fines" that have escaped capture in the sludge thickening process. In order to limit the impact of the sidestream solids, those plants so equipped should evaluate and

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utilize flocculant aids in or near the decant tank associated with the HT/WAO processes.

Supernatant Removal--

Reduce the variability in decanted liquid removal from the decant tank.

If the tank is an overflow type, the variability can be reduced by feeding the tank at a relatively constant rate. Although the feed rate is determined by the sludge treatment process, consideration should be given to the tank overflow when making feed changes.

If the tank utilizes manual removal of the decant liquid, the variability can be reduced by removing smaller volumes of decanted liquid more frequently. As an example, if it is determined that three feet of liquid must be removed daily from the tank, control the removal so that it occurs over 24 hours rather than during one shift (eight hours).

The operational methods generally available in HT/WAO to reduce quality/impact of the sidestream have been presented in this subsection. Return to the appropriate mainstream evaluation algorithm to determine whether the impact has been reduced to an acceptable degree or if design modifications are required to achieve further reductions.

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SECTION 6

DESIGN CONSIDERATION FOR POTW'S

DESIGN MODIFICATIONS FOR EXISTING POTW's

General

This section should be referred to only after all operational methods to control sidestream impacts have been implemented at the POTW. Proper use of the evaluation algorithms (logic flow diagrams) in Section 3 of this report assures that the design modifications in this section are only considered after operational methods have been implemented. In the event the operational methods have not been implemented, the user should refer to the User's Guide information in Section 2 of this report before continuing.

This section contains:

1. Instructions for Use.
2. Alternative Design Modifications Checklist.
    - Mainstream Processes
    - Sidestream Generators
3. Alternative Design Modifications for Mainstream Processes.
    - Address numbers $\boxed{1}$, $\boxed{2}$ or $\boxed{3}$
    - Address numbers $\boxed{10}$, $\boxed{11}$, $\boxed{12}$ or $\boxed{13}$
    - Address numbers $\boxed{20}$, $\boxed{21}$, $\boxed{22}$, $\boxed{23}$, $\boxed{30}$, $\boxed{31}$, $\boxed{32}$ or $\boxed{33}$
4. Page Location Matrix for Alternative Design Modifications for Sidestream Generators.
5. Alternative Design Modifications for Sidestream Generators.

Purpose

The purpose of this section is to provide information and guidance for determining and selecting design modifications to control sidestream impact at existing POTW's.

Selection of Alternative Modifications

Following implementation of operational methods to reduce sidestream impact, the user is referred to this section from the evaluation algorithms found in Section 3. (The checklist shown as Table 4 in Section 2 helps to keep a tally of those design modifications referenced.) This subsection can best be illustrated with the flow sheet in Figure 21.

Once the user is referred to this section via the block number from the evaluation algorithm checklist, the user must evaluate the applicability of Alternative Design Modifications and summarize them on a checklist (an example checklist is shown in Table 9). Go to the Page Location Matrix for Sidestream Generator Alternative Design Methods in this subsection and circle page numbers of applicable sidestream generator modifications. These modifications should be evaluated one at a time. When all modifications have been evaluated, the user should select and implement those which are most cost effective for the facility. Return to the Mainstream Treatment Process Evaluation Algorithm.

Alternative Design Modifications for Mainstream Processes

The Mainstream Design Modification Checklist, Table 9, is used to record the applicable alternatives from the alternative design modification tables, Tables 10, 11 and 12 for Primary, Activated Sludge and Trickling Filters/RBC, respectively.

Alternative Design Modifications for Sidestream Generators

The Sidestream Alternative Design Modification Page Location Matrix, Table 13, is used to locate modifications for the applicable sidestream. The Sidestream Design Modification Checklist, Table 14, is used to record feasible alternatives.

Following are 19 Alternative Design Modifications for various sidestream generators.

Anaerobic Digester (AnD-1)--
Mainstream Impact Parameter: BOD, TSS, Q

Modification Reference No.	Alternative Design Modification	Design Criteria for Modifications
1	Equalize supernatant return.	Provide 2 gal/cap of population equivalent contri-

Table 4

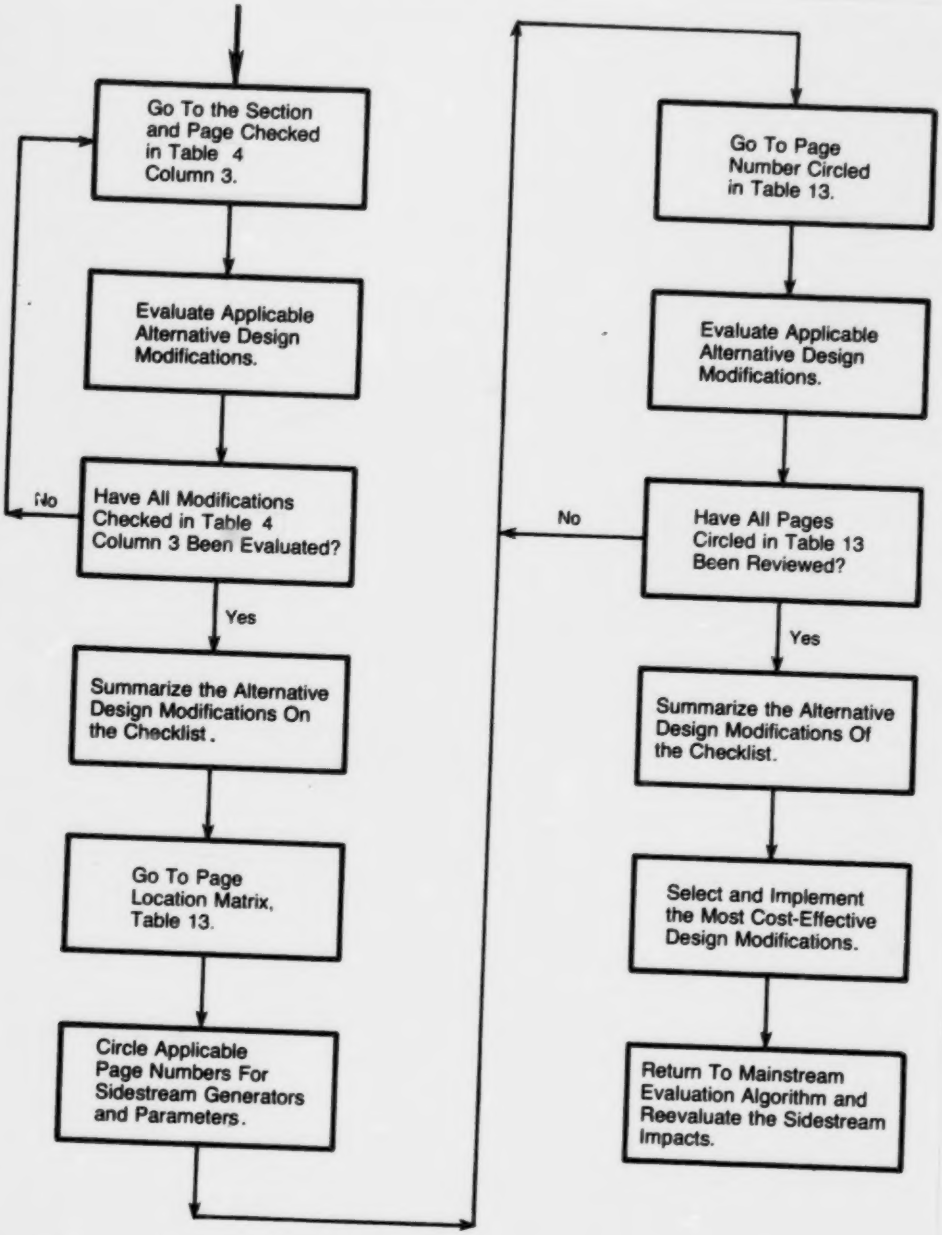
Go To the Section and Page Checked in Table 4 Column 3.
Evaluate Applicable Alternative Design Modifications.
Have All Modifications Checked in Table 4 Column 3 Been Evaluated?
No
Yes
Summarize the Alternative Design Modifications On the Checklist.
Go To Page Location Matrix, Table 13.
Circle Applicable Page Numbers For Sidestream Generators and Parameters.
Go To Page Number Circled in Table 13.
Evaluate Applicable Alternative Design Modifications.
Have All Pages Circled in Table 13 Been Reviewed?
No
Yes
Summarize the Alternative Design Modifications Of the Checklist.
Select and Implement the Most Cost-Effective Design Modifications.
Return To Mainstream Evaluation Algorithm and Reevaluate the Sidestream Impacts.

Figure 21. Flowsheet for selection and implementation of design modifications.

TABLE 9. MAINSTREAM DESIGN MODIFICATION CHECKLIST (ORIGINALLY TABLE 6)

Mainstream Reference Number	Modification Reference Number	Applicable Modification Alternative	Scheduled for Implementation	Implementation Completed
1	1	add conditioning chemicals		
	2	increase clarifier area		
	3	increase weir length		
2	1	increase clarifier area		
	2	install variable speed pump		
3	1	aerate grit chamber		
10	1	add conditioning chemicals		
	2	increase clarifier		
11	1	add pH control		
12	1	add conditioning chemicals		
	2	increase clarifier area		
	3	increase weir length		
13	1	increase aeration		
20 30	1	add filter area		
21 31	1	add pH control		
22 32	1	add conditioning chemicals		
	2	increase clarifier area		
	3	increase weir length		
23	1	increase recycle flow range		
	2	provide mechanical ventilation		
	3	increase specific surface		
	4	add filter area		
33	1	add filter area		
	2	increase rotation speed		
	3	aerate RBC channel		

TABLE 10. ALTERNATIVE DESIGN MODIFICATIONS FOR PRIMARY CLARIFICATION (PC)

- Address Numbers 1, 2, or 3

Evaluation Algorithm Reference Number	Observed Operational Impact Parameter	Alternative Design Modification(s)	Design Criteria for Modification(s)
1	Solids Loading (TSS)	1. Add conditioning chemicals: • organic polymers • inorganic salts (alum, ferric chloride, lime)	1. Provide for 1-5 min. mixing at G 100-200 sec^{-1}, flocculation for 15-30 min. G 10-50 Sec^{-1}) and a chemical dosage of: • 0-10 mg/L for polymers • 0-.500 mgu for salts
		2. Increase clarifier area by clarifier addition	2. $Q/A \leq 1000$ gpd/ft^2 with a detention (V/Q) of 90-120 min.
		3. Increase overflow weir length	3. O/F of weir $\leq$ 10,000 gpd/LF
2	Hydraulic Loading (Q)	1. Increase clarifier area by clarifier addition	1. $Q/A \leq 1000$ gpd/ft^2 with a detention (V/Q) of 90-120 min.
		2. Install variable speed influent pumping to reduce flow variation	2. Continuous influent flow at headworks
3	Effluent Dissolved Oxygen Concentration (DO)	1. Increase or install grit chamber aeration	1. 2-5 SCFM air/LF

TABLE 11. ALTERNATIVE DESIGN MODIFICATIONS FOR ACTIVATED SLUDGE (AS)

- Address Numbers $\boxed{10}$, $\boxed{11}$, $\boxed{12}$, or $\boxed{13}$

Evaluation Algorithm Reference Number	Observed Operational Impact Parameter	Alternative Design Modification(s)	Design Criteria for Modification(s)
$\boxed{10}$	Hydraulic Loading	1. Increase clarifier area by clarifier addition	1. $Q/A \leq 800$ gpd/ft^2 with a min SWD of 12 ft. and a maximum solids loading of 8 lb/hr/ft^2
		2. Add conditioning chemicals	2. Refer to $\boxed{1}$ - 2
$\boxed{11}$	pH	1. Add pH control system ahead	1. $6 \leq pH \leq 9$ with a maximum control loop delay of 15 min. between the pH signal and chemical addition
$\boxed{12}$	Solids	1. Refer to $\boxed{1}$ - 1	1. Refer to $\boxed{1}$ - 1
		2. Refer to $\boxed{1}$ - 1	2. $Q/A \leq 800$ gpd/ft^2 with a minimum SWD of 12 ft. and a maximum solids loading of 8 lb/hr/ft^2
		3. Refer to $\boxed{1}$ - 1	3. Refer to $\boxed{1}$ - 3
$\boxed{13}$	BOD	1. Increase air supply add aeration units or replace with higher efficiency units	1. $DO \geq 2$ mg/l; assume 1 μ = 0.8, $\beta = 0.9$

TABLE 12. ALTERNATIVE DESIGN MODIFICATIONS FOR TRICKLING FILTER/ROTATING BIOLOGICAL CONTACTOR (TF/RBC)

o Address Numbers $\boxed{20}$, $\boxed{21}$, $\boxed{22}$, $\boxed{23}$, $\boxed{30}$, $\boxed{31}$, $\boxed{32}$ or $\boxed{33}$

Evaluation Algorithm Reference Number	Observed Operational Impact Parameter	Alternative Design Modification(s)	Design Criteria for Modification(s)
$\boxed{20}$ $\boxed{30}$	Hydraulic	1. Add filter area	1. 4-10 mgd/acre (TF 2-4 gpd/ft^2 (RBC)
$\boxed{21}$ $\boxed{31}$	pH	1. Refer to $\boxed{11}$ - 1	1. Refer to $\boxed{11}$ - 1
$\boxed{22}$ $\boxed{32}$	Solids	1. Refer to $\boxed{12}$ - 1	1. Refer to $\boxed{12}$ - 1
		2. Refer to $\boxed{12}$ - 2	2. Refer to $\boxed{12}$ - 2
		3. Refer to $\boxed{12}$ - 3	3. Refer to $\boxed{12}$ - 3
$\boxed{23}$	BOD	1. Increase recycle flow range	1. Recycle flow = 2 : 1 forward flow
		2. Provide mechanical ventilation	2. $\geq$ 1 SCFM/ft^2 of filter area
		3. Increase specific surface	3. ft^2/ft^3 $\geq$ 50
		4. Same as $\boxed{20}$, $\boxed{30}$ - 1	4. Loading $\leq$ 30 $\frac{\text{16 BOD}}{\text{1000 ft}^3\text{-day}}$
$\boxed{33}$		1. Add filter area	1. $\leq$ 2 gpd/ft^2
		2. Increase rotation speed	2. Up to 20 RPM and/or tip velocity up to 30 ft/sec
		3. Provide aeration in the RBC channel	3. $\geq$ 1 SCFM/ft^2 of filter area

TABLE 13. SIDESTREAM ALTERNATIVE DESIGN MODIFICATION PAGE LOCATION MATRIX

Sidestream Generator	Mainstream Impact Parameter				
	BOD	TSS	pH	Q	DO
Gravity Thickener	-	110	-	113	111
Dissolved Air Flotation	-	110	-	113	-
Anaerobic Digester	100	100	-	100	112
Aerobic Digester	108	108	-	108	-
Vacuum Filter	108	110	113	-	112
Centrifuge	109	111	113	-	112
Belt Filter	109	111	113	-	112
Sand Bed	-	-	-	-	-
Lagoon	109	-	-	109	-
Heat Treatment	109	111	-	-	112
Wet Air Oxidation	109	111	-	-	112

TABLE 14. SIDESTREAM DESIGN MODIFICATION CHECKLIST

Sidestream Generator	Modification Reference Number	Applicable Design Modification Alternative	Scheduled for Implementation	Implementation Completed
Gravity Thickener	GT 1-1	add polymer system		
	2	add floculation center well		
	3	add supernatant equalization		
	4	increase SWD		
	GT 2 -1	add dilution water		
	2	equalize and aerate supernatant		
	GT 3 -1	add supernatant equalization		
Dissolved Air Flotation	DAF 1 -1	Add polymer system		
	2			
	DAF 3 -1	add supernatant equalization		
Anaerobic Digester	AnD 1-1	add supernatant equalization		
	2	increase supernatant withdrawal points		
	AnD 2 -1	equalize and aerate supernatant		
Aerobic Digester	AeD 1-1	add supernatant equalizer		
	2	Increase aeration and mixing		
	3	increase supernatant withdrawal point		
Vacuum Filter	VF 2 -1	add precoat		
	2	add filtrate equalization		
Centrifuge	C 2 -1	add second stage centrifuge		
	2	add centrate equalization		
Belt Filter	BF 2 -1	add filtrate equalization		
Vacuum filter, Centrifuge and Belt Filter	VF,C, BF 3 -1	equalize and aerate filtrate/ centrate		
	VF, C, BF 4 -1	elutriate sludge		
	2	add pH control		
Lagoon	LA 1 -1	add supernatant equalization		
Heat Treatment/Wet Air Oxidation	HT/WAO 1 -1, HT/WAO 2-1	minimize operating temp. & pressure		
	2, 3	equalize decant		
	HT/WAO 2 -2	add polymer system		
	HT/WAO 3 -1	add sidestream aerobic treatment		

Modification Reference No.	Alternative Design Modification	Design Criteria for Modifications
		buting to the plant with constant speed pumps each sized to return 2 gpd/capita.
2	Increase the number of supernatant withdrawal points.	Add piping such that supernatant may be returned at 2 ft intervals over the top 2/3 of the secondary digester depth. Specify a sludge density meter to avoid returning excessive solids.

Aerobic Digester (AeD-1)--
Mainstream Impact Parameter: BOD, TSS, Q

Modification Reference No.	Alternative Design Modification	Design Criteria for Modifications
1	Equalize supernatant return.	Refer to AnD-1, Mod. Ref. No. 1.
2	Increase aeration and mixing.	Add aeration equipment, if necessary, to maintain the DO ≥ 2 mg/L at all points in the digester. Check that at least 200 hp/mgal is provided for mixing.
3	Increase flexibility of supernatant withdrawal.	Refer to AnD-1, Mod. Ref. No. 2.

Vacuum Filter (VF-1)--
Mainstream Impact Parameter: BOD

Modification Reference No.	Alternative Design Modification	Design Criteria for Modifications
1	No applicable modifications. Modifications must be applied to upstream processes to reduce the filtrate soluble BOD level.	

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Centrifuge (C-1)--
Mainstream Impact Parameter: BOD

Modification Reference No.	Alternative Design Modification	Design Criteria for Modifications
1	Refer to VF Mod. Ref. No. 1.	

Belt Filter (BF-1)--
Mainstream Impact Parameter: BOD

Modification Reference No.	Alternative Design Modification	Design Criteria for Modifications
1	Refer to VF-1 Mod. Ref. No. 1.	

Lagoon (LA-1)--
Mainstream Impact Parameter: BOD, Q

Modification Reference No.	Alternative Design Modification	Design Criteria for Modifications
1	Equalize supernatant return.	Refer to AnD-1, Mod. Ref. No. 1.

Heat Treatment and Wet Air Oxidation (HT/WAO-1)--
Mainstream Impact Parameter: BOD

Modification Reference No.	Alternative Design Modification	Design Criteria for Modifications
1	Minimize operating temperature and pressure, consistent with acceptable conditioning.	Reduce temperature and pressure in 10° and 5 psi increments weekly. Measure and plot contours of supernatant soluble BOD and dewatered cake concentration versus temperature and pressure to determine the minimum operable point.
2	Equalize decant or dewatering supernatant return.	Refer to AnD-1, Mod. Ref. No. 1.

Gravity Thickener (GT-1)--
Mainstream Impact Parameter: TSS

Modification Reference No.	Alternative Design Modification	Design Criteria for Modifications
1	Add polymer system.	Allow for addition of up to 25 mg/L and/or 1% of polymer by weight compared to total TSS.
2	Add flocculating center well.	Provide 15 minutes of detention time with 100-200 sec of mixing.
3	Add supernatant equalization.	Provide for 48-hour detention time based on average flow, with 2 constant speed pumps sized for the average waste flow.
4	Increase SWD.	SWD ≥ 12 ft. 15 ft preferred.

Dissolved Air Flotation (DAF-1)--
Mainstream Impact Parameter: TSS

Modification Reference No.	Alternative Design Modification	Design Criteria for Modifications
1	Add polymer system.	Refer to GT-1, Mod. Ref. No. 1. Add polymer following pressure release.
2	Equalize supernatant return.	Refer to GT-1, Mod. Ref. No. 3.

Vacuum Filter (VF-2)--
Mainstream Impact Parameter: TSS

Modification Reference No.	Alternative Design Modification	Design Criteria for Modifications
1	Add precoat system and body feed.	Provide for 2 in. minimum thickness precoat with up to 50% by weight body feed. Cake knife sensitivity should be ± 1/6 in. or better.

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Modification Reference No.	Alternative Design Modification	Design Criteria for Modifications
2	Equalize supernatant return.	Refer to AnD-1, Mod. Ref. No. 1.

Centrifuge (C-2)--
Mainstream Impact Parameter: TSS

Modification Reference No.	Alternative Design Modification	Design Criteria for Modifications
1	Add a second stage centrifuge to cascade removal.	Requires field treatability studies to determine design criteria.
2	Equalize supernatant return.	Refer to AnD-1, Mod. Ref. No. 1.

Belt Filter (BF-2)--
Mainstream Impact Parameter: TSS

Modification Reference No.	Alternative Design Modification	Design Criteria for Modifications
1	Equalize supernatant return.	Refer to AnD-1, Mod. Ref. No. 1.

Heat Treatment and Wet Air Oxidation (HT/WAO-2)--
Mainstream Impact Parameter: TSS

Modification Reference No.	Alternative Design Modification	Design Criteria for Modifications
1	Refer to HT/WAO-2 Mod. Ref. No. 1.	Refer to AnD-1, Mod. Ref. No. 1, except plot TSS rather than BOD.
2	Add polymer system for decant system.	Refer to GT-1, Mod. Ref. No. 1.
3	Equalize supernatant.	Refer to HT/WAO-1, Mod. Ref. No. 2.

Gravity Thickener (GT-2)--
Mainstream Impact Parameter: DO

Modification Reference No.	Alternative Design Modification	Design Criteria for Modifications
1	Provide for dilution water input using heat effluent.	Provide for 0-200% of maximum waste flow in at least 50% increments.

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2	Equalize and aerate supernatant.	Refer to GT-1, Mod. Ref. No. 3. Also add 20 hp/mgd aeration.

Anaerobic Digester (AnD-2)--
Mainstream Impact Parameter: DO

Modification Reference No.	Alternative Design Modification	Design Criteria for Modifications
1	Equalize and aerate supernatant.	Refer to AnD-1, Mod. Ref. No. 1. Provide 20 hp/mgal for aeration.

Vacuum Filter, Centrifuge, and Belt Filter (VF, C, BF-3)--
Mainstream Impact Parameter: DO

Modification Reference No.	Alternative Design Modification	Design Criteria for Modifications
1	Equalize and aerate filtrate/centrate.	Refer to AnD-1, Mod. Ref. No. 1. Provide 20 hp/mgal for aeration.

Heat Treatment and Wet Air Oxidation (HT/WAO-3)--
Mainstream Impact Parameter: DO

Modification Reference No.	Alternative Design Modification	Design Criteria for Modifications
1	Equalize and aerate supernatant return.	This requires design of an aerobic biological treatment plant: Aeration (use complete mix only) Sludge age $\geq$ 10 days Hydraulic detention time $\geq$ 2 days MLSS = 4000-8000 mg/L DO $\geq$ 2 mg/L BOD:N:P = 100:5:1 6 $\leq$ pH $\leq$ 9 Secondary clarifier Q/A $\leq$ 600 gpd/ft^2 Q X/A $\leq$ 8 lb/day/ft^2 SWD $\geq$ 14 ft Polymer addition to flocculating center well.

Gravity Thickener and DAF (GT, DAF-3)--
Mainstream Impact Parameter: Q

Modification Reference No.	Alternative Design Modification	Design Criteria for Modifications
1	Equalize supernatant return.	Refer to AnD-1, Mod. Ref. No. 1.

Vacuum Filter, Centrifuge, and Belt Filter (VF, C, BF-4)--
Mainstream Impact Parameter: pH

Modification Reference No.	Alternative Design Modification	Design Criteria for Modifications
1	Elutriate sludge to minimize chemical dosage.	Wash sludge at 100 gpd/ft^2 with 50-200% of sludge flow, depending on desired alkalinity.
2	Add pH control (preferably following filtrate/centrate equalization).	Provide for single stage control with $\leq$ 15 minute lag between pH signal and acid/caustic addition point. Mix pH adjustment tank at 500 sec^{-1}.

Example--

Consider the POTW shown in Figure 22 with sidestreams from:

1. Dissolved air flotation.
2. Heat treatment.
3. Belt filtration.
4. Gravity thickener.
5. Anaerobic digestion.
6. Vacuum filtration.

It has been determined (from the operational algorithms) that mainstream processes are impacted by BOD, TSS, DO, flow and pH from some or all of the above units. We wish to investigate the sidestream impacts.

1. Given addresses $\boxed{1}$ to $\boxed{3}$, and $\boxed{10}$ to $\boxed{13}$, go to Table 10 for address $\boxed{1}$.

2. Determine feasibility of modifications and check applicable alternatives on the Mainstream Design Modification Checklist.

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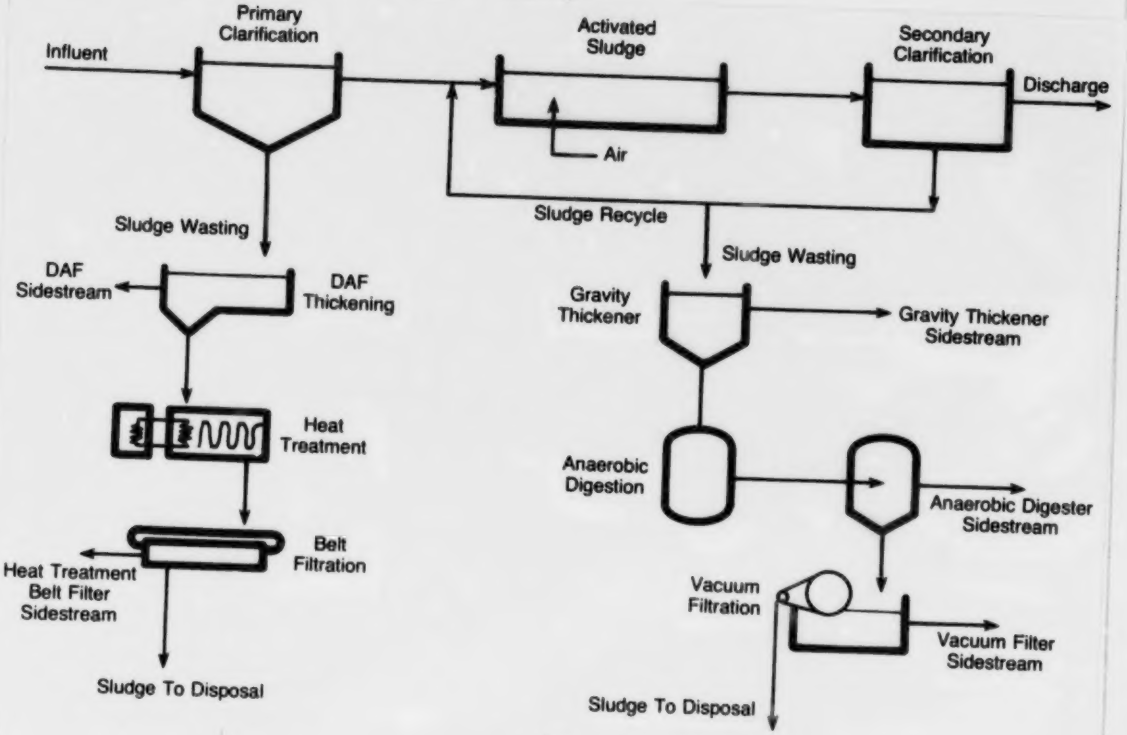
Influent
Primary Clarification
Activated Sludge
Air
Secondary Clarification
Discharge
Sludge Recycle
Sludge Wasting
DAF Sidestream
DAF Thickening
Heat Treatment
Belt Filtration
Heat Treatment Belt Filter Sidestream
Sludge To Disposal
Sludge Wasting
Gravity Thickener
Gravity Thickener Sidestream
Anaerobic Digestion
Anaerobic Digester Sidestream
Vacuum Filtration
Vacuum Filter Sidestream
Sludge To Disposal

Figure 22. Example of a publicly owned treatment works.

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3. Repeat steps 1 and 2 for addresses $\boxed{2}$ and $\boxed{3}$.
4. Go to Table 11 for address $\boxed{10}$.
5. Repeat step 2.
6. Repeat steps 4 and 5 for $\boxed{11}$, $\boxed{12}$ and $\boxed{13}$.
7. Go to the page location matrix table, and circle the applicable page numbers.
8. Go to the first circled page number.
9. Determine the feasibility of modifications and check applicable alternatives on the checklist.
10. Repeat step 9 for the next circled number until all alternatives have been evaluated.

We have now determined all of the feasible design modifications. Proceed to cost analysis and implement the most cost effective alternatives. Finally, reevaluate the plant using the mainstream evaluation algorithms.

DESIGN GUIDELINES

General Guidelines

This subsection presents guidelines for use by engineers in POTW design. It includes a summary table of sidestream flows, and BOD and TSS concentrations expected from 12 sidestream generators in 121 total process configurations. The guidelines presented are restricted to considerations of equalization, mixing, and aeration of the sidestreams, prior to their return to mainstream processes. A brief example is presented to demonstrate application of the guidelines.

Summary Table--

Table 8 (page 31) shows the expected sidestream quality from 12 sidestream generators in 121 process configurations. The values are recommended for use in design as discussed below.

Equalization, Mixing and Metering--

It can be seen from the summary table that with the exception of heat treatment (HT) and wet air oxidation (WAO), the average sidestream quality from the other sidestream generators does not represent a significant impact, per se, to the mainstream treatment processes. Problems that can be reasonably attributed to sidestreams are those which arise from the cyclic and non-uniform rate of return of sidestream material and the point of return. Therefore, design guidance to avoid the impact of sidestreams on mainstream treatment processes is divided into two parts; the first part dealing with all sidestreams other than those in which significant reaction occurs (such as heat treatment and wet air oxidation) and the second part dealing with those processes in which significant reaction does not occur. For each type of mainstream treatment process guidance is provided on the preferred point of return, as well as methods to provide a uniform return flow.

A major decision factor with respect to the point of return and the preferred method of sidestream collection and pretreatment depends on the presence or absence of aerated grit removal. The preferred point of return for nonreacting sidestreams is to the aerated grit chamber. This requires appropriate provisions in the design for additional air to provide a positive DO in the stream sent to primary clarification. In the event that primary clarification does not exist and is not contemplated in the process flow sheet, the preferred point of return is to the head end of the biological treatment process.

If aerated grit removal is part of the treatment process then the sidestream treatment process should consist of a basin to provide hydraulic equalization such that the total average flow of the sidestreams, as calculated from the summary table, is given 24-hour hydraulic equalization. From this equalization basin constant rate pumps should be provided. Specify a minimum of two pumps (each providing the 24-hour average flow rate) to direct the flow to the aerated grit chamber. The discharge of the pump should be provided with flow monitoring, pH monitoring, and solids density metering to prevent the return of unacceptable quality sidestreams for extended periods. The sidestream equalization basin should be instrumented to provide high and low level alarms as well as on and off control for the pumps. In the normal mode of operation it is expected that the sidestream equalization tank level will vary between the on-off limits for the pump such that a sidestream of relatively uniform quality is returned at uniform flow.

In the event aerated grit removal does not exist and is not contemplated in the process flow sheet, aeration should be added

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to the sidestream equalization and pumping described above to maintain a positive DO in the sidestream. This pretreatment should be used for all of the sidestreams except for heat treatment or wet air oxidation. An aeration input of approximately 20-horsepower per million gallons should be adequate. Where practicable, field testing should be performed to determine oxygen transfer characteristics of the equalized sidestreams and to provide sufficient aeration to maintain a positive dissolved oxygen level of approximately one milligram per liter in the equalization tank.

In the event that the mainstream process flow sheet does not include either aerated grit removal or primary clarification, care should be taken to subtract the expected level of solids in the aeration basin that could be attributed to solids returned from the sidestream treatment processes. If the solids being returned, for example, are nonbiodegradable they will represent an addition to the mixed liquor equal to the solids concentration returned from sidestream equalization times a multiplier which is the quotient of the mean cell residence time or sludge age and the hydraulic detention time of the aeration tank. Based on the amount of solids return, this figure could be significant and must be included in order to avoid the solids overloading of secondary clarifiers and improper control of the active sludge facility based on the mistaken assumption that all solids present are active biomass.

Heat Treatment and Wet Air Oxidation--

Heat treatment and wet air oxidation represent special cases among sidestream generators in that the return stream contains significant amounts of BOD and solids compared to the raw sewage (as shown in Table 8). The return stream, in terms of BOD, can represent a 50 percent additional load to the mainstream facility in terms of BOD and a 25 percent additional load in terms of suspended solids. Two major alternatives exist for avoiding sidestream impact on the mainstream process for these generators. The first requires addition of the expected sidestream load into the mainstream process flow sheet. Care must be taken to consider that the BOD returned from heat treatment and wet air oxidation may differ in their reactive qualities from the BOD in the raw sewage. The other major alternative is to provide a separate treatment facility for the sidestream prior to its reintroduction into the mainstream. If the sidestream treatment effluent is of sufficient quality, then it may be mixed with the mainstream effluent prior to discharge. This, in effect, requires designing a treatment facility for a stream which could contain up to 50 percent of the BOD loading and 25 percent of the solids loading of the raw wastewater in as little as one percent of the flow. Therefore, some type of treatment which is capable of handling high concentrations of BOD and solids without undue economic penalty is indicated.

Design Process

The impact of sidestreams on the operation of a POTW can be minimized by providing flow equalization. Two types of flow equalization are available: in-line equalization and off-line equalization. With in-line equalization, all flow passes through the equalization basin; however, with off-line equalization, only the flow which is above the daily average is diverted to the equalization basin. For sidestream integration, in-line equalization is preferable because it provides better damping of constituent mass loadings to downstream processes.

Design of a sidestream equalization system involves four aspects:

1. Determining the daily sidestream volume.
2. Calculating the equalization basin dimensions.
3. Sizing the pumps.
4. Specifying the mixer.

The design process can best be illustrated by the following examples. In these examples, it is assumed that an equalization basin large enough to contain a 24-hour sidestream volume is provided. (The equalization basin volume can also be calculated by developing a cumulative mass curve of the sidestream flow rate. Details of this procedure can be found in Reference No. 75, pp. 187-195.)

Example --
Integration of the sidestream volume from the process train Primary + Activated Sludge + Heat Treatment + Vacuum Filtration (P+AS+HT+VF).

- Daily Sidestream Volume

The daily (24-hour) sidestream volume for this process train is the sum of the sidestreams from heat treatment and vacuum filtration. The daily sidestream volume is 17,570 gallons. Additional volume should be provided for occasional variations in sidestream flow. For this example, an additional 20 percent (i.e., a safety factor of 1.2) was provided.

Daily Sidestream Volume = 17,570 gal x 1.2 = 21,085 gal

- Equalization Basin Dimensions

To determine the optimal configuration for the equalization

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basin, various combinations of dimensions should be calculated; for instance, several depths, as well as square, circular, and rectangular surface configurations should be investigated.

Effective Basin Volume Required = 21,085 gal x 0.134 ft^3/ gal = 2,820

Side-Water Depth (ft)	Surface Area (ft^2)	Surface Dimensions (ft) Square	Surface Dimensions (ft) Circular (diameter)	Surface Dimensions (ft) Rectangular (2:1 L:W)
5	564	24x24	27	34x17
8	353	19x19	21	26x13
10	282	17x17	19	24x12
15	188	14x14	16	20x10

Increase the depth by 8 ft (3 ft freeboard and an additional 5 ft to protect the mixer).

- Pumping Rate

A flow-control valve or pumps are required to regulate the flow from the equalization basin to downstream units.

The pumping rate is based on the effective basin volume (21,085 gal).

$$\text{Pumping Rate} = 21{,}085\ \frac{\text{gal}}{\text{day}}\ \frac{60\ \text{min}}{\text{hr}} \times \frac{24\ \text{hr}}{\text{day}} = 15\ \text{gpm}$$

Provide multiple pumps to ensure system reliability.

If constant-speed pumps are chosen, a throttling valve should be provided at the pump discharge in order to adjust the flow.

- Mixer Sizing

Mixing is required to keep solids in suspension, to blend the contents of the tank, and to prevent the wastewater from becoming septic.

A rule-of-thumb for mixer sizing is to provide 0.02-0.04 hp/ 1,000 gallons of storage. (Use 0.04 hp/1,000 gal for a conservative estimate.)

EPA Form 2350-1 (4-80)
(PREVIOUSLY CIN. EPA FORM 297)
TYPING GUIDE SHEET

Arbitrarily choosing basin dimensions 17 ft x 17 ft x (10 ft SWD + 3 ft FB + 5 ft), the actual equalization basin volume is 5,200 ft^3 or 38,900 gal. The horsepower requirement is calculated as follows:

$$\text{Horsepower Requirement} = \frac{0.04 \text{ hp}}{1{,}000 \text{ gal}} \times 38{,}900 \text{ gal} = 1.6 \text{ hp}$$

EPA Form 2320-4 (4-80)
(PREVIOUSLY CIN: EPA FORM 227)
TYPING GUIDE SHEET

REFERENCES

1. Ahlberg, N.R. and Boyko, B.I., 1972.
"Evaluation and Design of Aerobic Digesters", *Jour. Water Pollution Control Federation, 44* (4): 634.

2. Albertson, O. E. and Guidi, E.E., 1969.
"Centrifugation of Waste Sludges", *Jour. Water Pollution Control Federation, 41* (4): 607.

3. Alford, J.M., 1969.
"Sludge Disposal Experiences at North Little Rock, Arkansas", *Jour. Water Pollution Control Federation, 41* (2), Part 1: 175.

4. Allen and Hoshall, Inc., 1977.
Analysis of Alternatives for Sludge Thickening and Dewatering Equipment for the T. E. Maxon and North Wastewater Treatment Plants, City of Memphis, TN.

5. Antonie, R. L., 1976.
"Rotating Biological Contactor for Secondary Wastewater Treatment", Paper Presented at the Culp/Wesner/Culp WWT Seminar, Stateline, Nevada, Oct. 27-28, 1976.

6. Asano, T., Suzuki, T., and Hayakawa, N., 1977.
"Centrifugal Dewatering of Municipal and Industrial Sludge", *Water and Sewage Works, 124* (9): 130.

7. Austin, E.P., 1978.
"The Filter Belt Press - Application and Design", *Filtration and Separation* (U.K.), *15* (4): 320.

8. Bare, W.F.R., Jones, N.B. and Middlebrooks, E.J., 1975.
"Algae Removal Using Dissolved Air Flotation", *Jour. Water Pollution Control Federation, 43* (1): 153.

9. Baskerville, R.C., Bruce, A.M. and Day, M.C., 1978.
"Laboratory Techniques for Predicting and Evaluating the Performance of a Filterbelt Press", *Filtration and Separation* (U.K.), *15* (9): 445.

10. Bassett, D.J., Tolaney, M. and Conarroe, K., 1978. "Performance Comparison of Filter Press, Belt Press and Centrifuge Units for Dewatering of Citrus Processing/Activated Sludge", *Proc. 33rd Ind. Waste Conference, Purdue University*, *33*: 113.

11. Bennett, E.R., Rein, D.A. and Linstedt, K.D., 1973. "Economic Aspects of Sludge Dewatering and Disposal", *Jour. of the Env. Eng. Div. ASCE, EEI*: 55.

12. Bennett, G.E., 1970. *Development of a Pilot Plant to Demonstrate Removal of Carbonaceous, Nitrogenous and Phosphorous Materials from Anaerobic Digester Supernatant and Related Process Streams*, Water Pollution Control Series, NTIS Accession No. PB-196 733.

13. BIF Purifax Technical Bulletin, 1972. *Municipal Applications of the Purifax Process*. Bulletin No. PFX 1.21-7 (4/72).

14. BIF Purifax Technical Bulletin, 1972. *Comparison of Sludge Stabilization Methods*, Bulletin No. PFX 1.21-6 (5/72).

15. BIF Purifax Technical Bulletin, 1973. *Sludge Production Table and Purifax Sizing Procedure*. Bulletin No. PFX 1.21-1.

16. BIF Purifax Technical Bulletin, 1973. Bulletin No. PFX 1.21-9 (4/73).

17. Bitanja, H.H.J., Brunsmann, J.J. and Boelhouwer, C., 1975. "The Use of Oxygen in a Rotating Disk Process", *Water Research* (U.K.) *10*: 561.

18. Bizjak, G.J. and Becher, A. E., 1978. "Wausau Solves Dual Problem by Using Filter Press", *Water and Wastes Engineering, 15*: 28.

19. Boyle, J.D. and Gruenwald, D.D., 1975. "Recycle of Liquor from Heat Treatment of Sludge", *Jour. Water Pollution Control Federation, 47* (10): 2482.

20. Breaz, E., 1972. "Drug Firm Cuts Sludge Handling Costs", *Water and Wastes Engineering, 9* (1): A-22.

21. Burd, R.S., 1968.
A Study of Sludge Handling and Disposal. Water Pollution Control Research Series Publication No. WP-20-4 (Federal Water Pollution Control Administration, U.S. Department of the Interior).

22. Burris, M.A., Cosens, K.W. and Mair, D.M., 1976.
"Softening and Coagulation Sludge-Disposal Studies for a Surface Water Supply", *Jour. Amer. Water Works Assoc*., 247.

23. Caldwell, D.H., Parker, D.S., Uhte, W.R., and Stenquist, R.J., 1973. *Upgrading Lagoons*. U.S. EPA Technology Transfer Publication No. EPA-625/4-73-001 b (Revised June 1977).

24. Campbell, H.W., Rush, R.J., and Tew, R., 1978.
Sludge Dewatering Design Manual, Wastewater Technology Centre, Environmental Protection Service, Fisheries and Environment, Canada, Project No. 75-3-22.

25. Carnes, B.R. and Eller, J.M., 1978.
Characterization of Wastewater Solids", *Jour. Water Pollution Control Federation, 44* (8): 1498.

26. Cassel, A.F. and Johnson, B.P., 1978.
"Toward Better Incineration: New Press Evaluated", *Water & Sewage Works, 125* (11): 49.

27. Christensen, G.L., Elliott, W.R. and Johnson, W.K., 1976.
"Interactions Between Sludge Conditioning, Vacuum Filtration, and Incineration", *Jour. Water Pollution Control Federation, 48* (8): 1955.

28. Clark, E. I. and Fisk, B., 1978.
"Dewatering of Mixed Sludges", *Water Pollution Control* (U.K.), *77* (4): 509.

29. Clough, G.F.G., 1977.
"The Effect of Sludge Treatment Processes on the Design and Operation of Sewage Treatment Plants", *Water Pollution Control* (U.K.), *76*: 452.

30. Corrie, K.D., 1972.
"Use of Activated Carbon in the Treatment of Heat-Treatment Sludge Liquors", *Water Pollution Control* (U.K.), *71*: 629.

31. Crockford, J.B. and Sparham, V., 1972. "Developments to Upgrade Settlement Tank Performance, Screening, and Sludge Dewatering Associated with Industrial Wastewater Treatment", Proc. 27th Ind. Waste Conf., Purdue Univ., 27: 1072.

32. Culp, G.L. and Heim, N.F., 1978. Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities. EPA Publication #EPA-430/9-78-001.

33. Dick, R.I. and Ball, R.O., 1979. "Sludge Dewatering", a review prepared for Critical Review in Environmental Control, edited by C.P. Staub. CRC Press, Inc., Cleveland, Ohio.

34. Dick, R.I., Simmons, D.L., Ball, R.O., Perlin, K., and O'Hara, M.W., 1978. Process Selection for Optional Management of Regional Wastewater Residuals. Department of Civil Engineering, University of Delaware, supported by National Science Foundation Applied Science and Research Applications Directorate Grant No. ENV 75-15751-A01.

35. Dust, J., 1956. "Sludge Thickening Proves Economical in Beaumont, Texas, Sewage Treatment Plant", Civil Engineering, 26: 68.

36. Eichmann, B.W., 1977. "Dewatering Machine Solves Sludge Drying Problems", Water & Sewage Works, 124 (10): 99.

37. Erickson, A.H. and Knopp, P.V., 1972. "Biological Treatment of Thermally Conditioned Sludge Liquors", in Advances in Water Pollution Control, edited by S.H. Jenkins, Pergamon Press, New York, p. II-33/1.

38. Erickson, C.V., 1945. "Treatment and Disposal of Digestion Tank Supernatant Liquor", Sewage Works Journal, 17 (5): 889.

39. Ettelt, G.A., 1968. "Activated Sludge Thickening by Dissolved Air Flotation", Proc. of the 19th Ind. Waste Conf., Purdue Univ., 19: 210.

40. Ettelt, G.A. and Kennedy, T.J., 1966. "Research and Operational Experience in Sludge Dewatering", Jour. Water Pollution Control Federation, 38 (2): 250.

41. Famularo, J., Mueller, J.R., and Mulligan, T., 1978. "Application of Mass Transfer to Rotating Biological Contactors", *Jour. Water Pollution Control Federation, 50* (4): 653.

42. Garrison, W.E., Stahl, J.F., Tortorici, L., and Miele, R.P., 1978. "Pilot-Plant Studies of Waste Activated Sludge Processing", *Jour. Water Pollution Control Federation, 50* (10): 2374.

43. Geinopolos, A. and Vilen, F.I., 1971. "Process Evaluation - Phosphorus Removal", *Jour. Water Pollution Control Federation, 43* (10): 1975.

44. Grace, H.P., 1959. Annual Review of Unit Operations: Filtration. *Indus. Eng. Chem., 51* (3), Part II: 354.

45. Gruninger, R.M. "Disposal of Waste Alum from Water Treatment Plants", *Jour. Water Pollution Control Federation, 47* (3): 543.

46. Gulas, V., Lindsey, R., Benefield, L., and Randall C., 1978. "Factors Affecting the Design of Dissolved Air Flotation Systems", *Jour. Water Pollution Control Federation, 50* (7): 1835.

47. Hathaway, S.W. and Olexsey, R.A., 1977. "Improving Sludge Incineration and Vacuum Filtration with Pulverized Coal", *Jour. Water Pollution Control Federation, 49* (11): 2419.

48. Haug, R. T., 1977. "Sludge Processing to Optimize Digestibility and Energy Production", *Jour. Water Pollution Control Federation, 49* (7): 1713.

49. Haug, R.T., Tortorici, L.D., and Raksit, S.K., 1977. *LA/OMA Project: Sludge Processing and Disposal.* Los Angeles/Orange County Metropolitan Area, (California).

50. Haug, R.T., Raksit, S.K., and Wang, G., 1977. "Anaerobic Filter Treats Waste Activated Sludge", *Water and Sewage Works, 124* (2): 40.

51. Hurwitz, E.M. and Dundas, W.A., 1960. "What Are the Residues of Wet Combustion of Sludge?", *Wastes Engineering, 31* (3): 178.

52. Jaworski, N., Lawton, G.W. and Rohlich, G.A., 1960. "Aerobic Sludge Digestion", Presented at the Conference on Biological Waste Treatment, Manhattan College, N.Y., N.Y., (April 20-22, 1960), p. 93.

54. Jennett, C. and Harris, D.J., 1973. "Environmental Effects on Sludge Drying Bed Dewatering", Jour. Water Pollution Control Federation, 45 (3): 449.

55. Kalinske, A.A., 1976. Municipal Wastewater Treatment Plant Sludge and Liquid Sidestreams. EPA Technical Report No. EPA-430/9-76-007 (NTIS Accession No. PB-255 769).

56. Kalinske, A.A., 1978. "Sludges and Sidestreams Go Hand-in-Hand", Water & Wastes Engineering, 15 (2): 25.

57. Kappe, S.E., 1958. "Digester Supernatant: Problems, Characteristics, and Treatment", Sewage and Industrial Wastes, 30 (7): 937.

58. Karr, P.R. and Keinath, T.M., 1978. "Influence of Particle Size on Sludge Dewaterability", Jour. Water Pollution Control Federation, 50 (8): 1911.

59. Katz, W.J. and Geinopolos, A., 1968. "Concentration of Sewage Treatment Plant Sludges by Thickening", Proc. Tenth Sanitary Engineering Conf. (Waste Disposal from Water and Wastewater Treatment Processes), University of Illinois (Feb. 6-7, 1968).

60. Katz, W.J. and Geinopolos, A., 1967. "Sludge Thickening by Dissolved air Flotation", Jour. Water Pollution Control Federation", 39 (6): 946.

61. Keefer, C.E., 1960. "Thickening of Raw Sludge", Water & Sewage Works, 107 (2): 218.

62. Keefer, C.E. and Kratz, H., 1940. "Treatment of Supernatant Sludge Liquor by Coagulation and Sedimentation", Sewage Works Journal, 12 (4): 738.

63. Kelsey, G.D., 1965. "Some Practical Aspects of Continuous Rotary Vacuum Filters", Trans. Instn. Chem. Engrs., 43: T248.

64. Komline, T.R. "Dissolved Air Flotation Tackles Sludge Thickening", Water & Wastes Engineering, 15: 63.

65. Komoski, R.E., Puckett, J.C. and Childers, J.B., 1977. "Precoat Filtration of Waste Activated Sludge", Proc. 32nd Ind. Waste Conf., Purdue Univ., 32: 603.

66. Kurita, T. and Suwa, S., 1978. "How the Fully Automatic Filter Press Has Developed", Filtration & Separation, 15 (2): 109.

67. Laboon, J.F., 1952. "Experimental Studies on the Concentration of Raw Sludge", Sewage and Industrial Wastes, 24 (4): 423.

68. Leary, R.D., Ernest, L.A., Douglas, G.R., Geinopolos, A., and Mason, D.G., 1974. "Top-Feed Vacuum Filtration of Activated Sludge", Jour. Water Pollution Control Federation, 46 (7): 1961.

69. Leonard, R.J. and Parrott, S.W. "Sludge Dewatering at Rohm and Haas Houston Plant", Proc. 33rd Ind. Waste Conf., Purdue Univ., 33: 661.

70. Lindsey, A.M., 1968. "Dewatering Paper Mill Sludge by Vacuum Filtration", Proc. 23rd Ind. Waste Conf., Purdue Univ., 23: 438.

71. Lockyear, C.F., 1979. "Sludge-Thickenability Test Using a Low-Speed Centrifuge", Effluent and Water Treatment Jour. (U.K.), 19 (5): 223.

72. Malina, J.F. and DiFilippo, J., 1971. "Treatment of Supernatants and Liquids Associated with Sludge Treatment", Water and Sewage Works, 1971 Reference Number: R-30.

73. Mavinic, D.S. and Koers, D.A., 1979. "Performance and Kinetics of Low-Temperature, Aerobic Sludge Digestion", Jour. Water Pollution Control Federation 51 (8): 2088.

74. McCarty, P.L., 1966. "Sludge Concentration - Needs, Accomplishments, and Future Goals", Jour. Water Pollution Control Federation, 38 (4): 493.

75. Metcalf and Eddy, Inc., 1979. Wastewater Engineering: Treatment, Disposal, Reuse. McGraw-Hill, Inc., New York

76. Mignone, N.A., 1976.
"Anaerobic Digester Supernatant Does Not Have to be a Problem", Water and Sewage Works, 123 (12): 57.

77. Mignone, N.A., 1977 a.
"Survey of Anaerobic Digestion Supernatant Treatment Alternatives", Water and Sewage Works, 124 (1): 42.

78. Mignone, N.A., 1977 b.
"Elimination of Anaerobic Digester Supernatant", Water and Sewage Works, 124 (2): 48.

79. Miller, S.A., 1957.
"Annual Review of Unit Operations: Filtration". Indus. Eng. Chem. 49 (3), Part II: 486.

80. Mudgett, C.T., 1941.
"Sludge Filtration at Muskegon, Michigan", Sewage Works Journal, 13 (5): 879.

81. Mulbarger, M.C. and Huffman, D.D., 1970.
"Mixed Liquor Solids Separation by Flotation", Jour. of the Sanitary Engineering Division-ASCE, SA-4, 861.

82. Mulbarger, M.C., Page, G.L., Yates, O.W., and Sharp, N.C., 1969.
"Manassas, Va., Adds Nutrient Removal to Waste Treatment", Water and Wastes Engineering, 6 (4): 46.

83. Nelson, J.K. and Tavery, M.A.H., 1978.
"Chemical Conditioning Alternatives and Operational Control for Vacuum Filtration", Jour. Water Pollution Control Federation, 50 (3): 507.

84. Nogas, R. and Hurwitz, E., 1963.
"Making Supernatant Behave!", Wastes Engineering, 34 (5): 230.

85. Novak, J.T. and Langford, M., 1977.
"The Use of Polymers for Improving Chemical Sludge Dewatering on Sand Beds", Jour. Amer. Water Works Assoc, 69: 106.

86. Ohara; G.T., Raksit, S.K. and Olson, D.R., 1978.
"Sludge Dewatering Studies at Hyperion Treatment Plant", Jour. Water Pollution Control Federation, 50: 912.

87. Parkhurst, J.D., Miele, R,P., Hayashi, S.T., and Rodrique, R.F., 1974. "Dewatering Digested Primary Sludge", Jour. Water Pollution Control Federation, 46 (3): 468.

88. Pitzer, R.L., Wukash, R.F. and Wells, D.B., 1977. "The Vacuum Filtration of Sewage Sludge using Crushed Coal as a Conditioning Agent," Proc. 32nd Ind. Waste Conf., Purdue Univ., 32: 29.

89. Prakasam, T.B.S., Robinson, W.E. and Lue-Hing, C., 1977. "Nitrogen Removal From Digested Sludge Supernatant Liquor Using Attached and Suspended Growth Systems," Proc. 32nd Ind. Waste Conf., Purdue Univ., 32: 745.

90. Randall, C.W., Turpin, J.K. and King, P.H., 1971. "Activated Sludge Dewatering Factors Affecting Drainability," Jour. Water Pollution Control Federation, 43 (1): 102.

91. Ritter, L.E., 1970. "Design and Operating Experiences Using Aeration for Sludge Digestion," Jour. Water Pollution Control Federation, 42 (10): 1782.

92. Roberts, K.L., Weeter, D.W. and Ball, R.O., "Dissolved Air Flotation Performance," Proc. 33rd Ind. Waste Conf., Purdue Univ., 33: 194.

93. Rudolfs, W. and Gehm, H.W., 1939. "High and Low Temperature Digestion - VI. Supernatant Liquor Treatment with Chemicals," Sewage Works Jour., 11 (1): 19.

94. Sawyer, B.M., Watkins, R., and Lue-Hing, C., 1967. "Evaluation of Unit Processes for Mechanical Dewatering of Anaerobically Digested Sludge at Metro Chicago's West-Southwest Sewage Treatment Plant," Proc. 31st Ind. Waste Conf., Purdue Univ., 31: 537.

95. Schlenz, H.E., 1944. "Controlled Digestion", Sewage Works Jour., 16 (3): 504.

96. Schmidt, R.K., Thompson, J.G. and Bell, J.A., 1976. "A Bench-Mark Study - Industrial Operating Experience with the Gravity/Pressure Sludge Dewatering Principle," Proc. 31st. Ind. Waste Conf., Purdue Univ., 31: 554.

97. Shirato, M., Sambuichi, M., Kato, H., and Aragaki, T., 1969.
"Internal Flow Mechanism in Filter Cases," AICHE Journal, 15 (3): 405.

98. Silverman, S.H., 1979.
Project Report: City of Philadelhia, PA, Southwest Water Pollution Control Plant, Sludge Dewatering Station Improvements." Publication of Bird Machine Company.

99. Sommers, L.E. and Curtis, E.H., 1977.
"Wet Air Oxidation: Effect on Sludge Composition," Jour. Water Pollution Control Federation, 49 (11): 2219.

100. Sorrles, J.H. and Zeller, P.J.A., 1963.
"Supernatant on Trickling Filters," Jour. Water Pollution Control Federation, 35 (11): 1419.

101. Smith, R., 1968.
"Preliminary Design and Simulation of Conventional Wastewater Renovation Systems Using the Digital Computer. Water Pollution Control Research Series Publication No. WP-20-9. U.S. Department of Interior, Federal Water Pollution Control Administration, Cincinnati, Ohio.

102. Stahl, W., 1978.
"Cost/Performance Comparisons Between Disc and Drum Filters," Filtration and Separation (U.K.), 15 (1): 38.

103. Swets, D.H., Pratt, L. and Metcalf, C.C., 1974.
"Thermal Sludge Conditioning in Kalamazoo, Michigan," Jour. Water Pollution Control Federation, 46 (3): 575.

104. Stanbridge, H.H., 1968.
"Operation and Performance of the Hogsmill Valley Sewage Treatment Works of the Greater London Council, 1958-1966", Water Pollution Control (U.K.), 67: 21.

105. Tletzke, G.H., Gitchel, W.B., Diddams, D.G., and Hoffman, C.A., 1967.
"Components of Sludge and Its Wet Air Oxidation Products," Jour. Water Pollution Control Federation, 39 (6): 994.

106. Tiller, F.M., 1978.
"Characteristics of Staged, Delayed-Cake Filters," Filtration Separation, 15 (3): 204.

107. Torpey, W.N. and Melbinger, N.R., 1967. "Reduction of Digester Sludge Volume by Controlled Recirculation", Jour. Water Pollution Control Federation, 39 (9): 1464.

108. Turkki, E.V., Hildebrand, A.S., and Nemerow, N.L., 1975. "Removal of Fine Solids From Chemical Waste Stream Through Precoat Rotary Vacuum Filtration," Proc. 30th Ind. Waste Conf., Purdue Univ., 30: 358.

109. Van Fleet, G.L. and Harris, A. J., 1974. "Treatment and Disposal of Chemical Phosphate Sludge in Ontario," Jour. Water Pollution Control Federation, 46 (3): 582.

110. University of Tennessee.

111. U.S. Environmental Protection Agency, 1974. Flows Equalization. Technology Transfer Publication No. EPA 625/4-74-006.

112. U.S. Environmental Protection Agency, 1974. Process Design Manual for Upgrading Existing Wastewater Treatment Plants. Technology Transfer Publication No. EPA 625/1-71-004a.

113. U.S. Environmental Protection Agency, 1976. Areawide Assessment Procedures Manual, Volume III, "Appendix H, Point Source Control Alternatives: Performance and Cost". Municipal Environmental Research Laboratory, Office of Research and Development, Publication No. EPA 600/9-76-014.

114. U.S. Environmental Protection Agency, 1978. Needs Survey Data (1978). Personal Communication with Jon Bender, U.S. EPA Municipal Environmental Research Laboratory, Cincinnati, Ohio.

115. Vaughn, D.R. and Reitwiesner, G.A., 1972. "Disc-Nozzle Centrifuges for Sludge Thickening," Jour. Water Pollution Control Federation, 44 (9): 1789.

116. Vesilind, P.A., 1975. Treatment and Disposal of Wastewater Sludges, Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan.

117. Villiers, R.V. and Farrell, J.N., 1977. "A Look at Newer Methods for a Dewatering Sewage Sludge," Civil Engineering, 47 (12): 66.

118. Voshel, D., 1966.
"Sludge Handling at Grand Rapids, Michigan, Wastewater Treatment Plant," Jour. Water Pollution Control Federation, 38 (9): 1506.

119. Walker, J.T., 1978.
"Unique Sludge Handling System Chosen in Dubuque," Water & Wastes Engineering, 15: 20.

120. Water Pollution Control Federation, 1969.
Sludge Dewatering, Manual of Practice No. 20.

121. Water Pollution Control Federation, 1977.
Wastewater Treatment Plant Design, Manual of Practice No. 8.

122. Zenz, D.R., Sawyer, B., Watkins, R., Lue-Hing, C., Richardson, G., 1978.
"Evaluation of Dewatering Equipment for Anaerobically Digested Sludge", Jour. Water Pollution Control Federation, 50 (8): 1965.

APPENDIX A

RANKING OF PROCESS MATRIX

INTRODUCTION

A process matrix was developed in order to investigate sidestream strengths and loads typical of various types of POTW's, determine their impact on overall POTW performance and effluent quality, and develop operational evaluation and mitigation methods, design modifications, and design guidelines. The process matrix contains the mainstream treatment processes and sidestream generators to be evaluated. Elements of the matrix are:

1. Mainstream treatment processes

    - Primary clarification (P)
    - Activated sludge (AS)
    - Trickling filter (TF)
    - Rotating biological contactor (RBC)

2. Sidestream generator/sidestream

    - Gravity thickener (GT)/supernatant
    - Dissolved air flotation (DAF)/subnatant
    - Anaerobic digestion (AnD)/supernatant
    - Aerobic digestion (AeD)/supernatant (decant)
    - Vacuum filter (VF)/filtrate
    - Centrifuge (C)/centrate
    - Belt filter press (BF)/filtrate
    - Sand drying bed (SB)/under-drainage liquor
    - Sludge lagoon (LA)/supernatant
    - Heat treatment (HT)/liquor
    - Wet air oxidation (WAO)/liquor
    - Pressure filter (filter press)(FP)/filtrate
    - Purifax (PX)/supernatant, filtrate, subnatant, or under-drainage liquor

It was necessary to enumerate the matrix and develop "typical" wastewater treatment process flow schemes prior to initiating the preliminary evaluation.

Process Matrix

The matrix of mainstream treatment processes and sidestream generators is presented in Table A-1. The single-stage anaerobic digestion and two-stage anaerobic digestion were combined into a single category titled anaerobic digestion as sufficient information and data could not be found to warrant the separate categories.

Enumerated Matrix

Prior to initiating evaluation of the matrix, it was necessary to enumerate the matrix and develop "typical" wastewater treatment flow process schemes. While the matrix contains 46 elements, the nature of the sidestream generated from a particular operation/process is dependent on the treatment operations/ processes which precede and follow. A sidestream from a vacuum filter will have different characteristics if it is preceded by gravity thickening and anaerobic digestion than if it is preceded by dissolved air flotation and aerobic digestion. The elements of the process matrix presented on Table A-1 were transferred to an evaluation matrix, Figure A-1. When fully enumerated, this matrix contains over 1,300 sidestreams with potentially different characteristics.

If other elements are introduced (e.g., separate digestion and/or thickening for primary treatment processes, or thickening before and after digestion) the number of possibilities could grow into the tens of thousands. Evaluation of that many possibilities was not feasible; therefore, "typical" treatment flow process schemes were developed for evaluation (Figures A-2 and A-3). When Figures A-2 and A-3 are enumerated, the number of potentially different sidestreams which could be generated are 701.

In order to reduce the number of potentially different sidestreams further,six other simplifications were incorporated. These six simplifications are:

1. All secondary treatment processes are preceded by primary clarification.

2. Centrifugation was not considered as a thickening operation.

3. Digestion, heat treatment, and wet air oxidation processes are preceded by thickening.

TABLE A-1. PROCESS MATRIX

Sidestream Generator	Treatment Process			
	Primary (P)	Activated Sludge (AS)	Trickling Filter (TF)	Rotating Biological Contactor (RBC)
Gravity Thickener (GT)	○	●	●	●
Dissolved Air Flotation (DAF)	○	●	●	●
Anaerobic Digestion (AnD)	●	●	●	●
Aerobic Digestion (AeD)	○	●	○	○
Vacuum Filter (VF)	●	●	●	●
Centrifuge (C)	●	●	●	●
Belt Filter Press (BF)	●	●	●	●
Sand Drying Bed (SB)	●	●	●	●
Lagoon (LA)	○	●	●	●
Heat Treatment (HT)	●	●	●	●
Wet Air Oxidation (WAO)	●	●	●	●
Pressure Filter (Filter Press, FP)	●	●	●	●
Purifax(PX)	●	●	●	●

○ No evaluation required
● Evaluation required

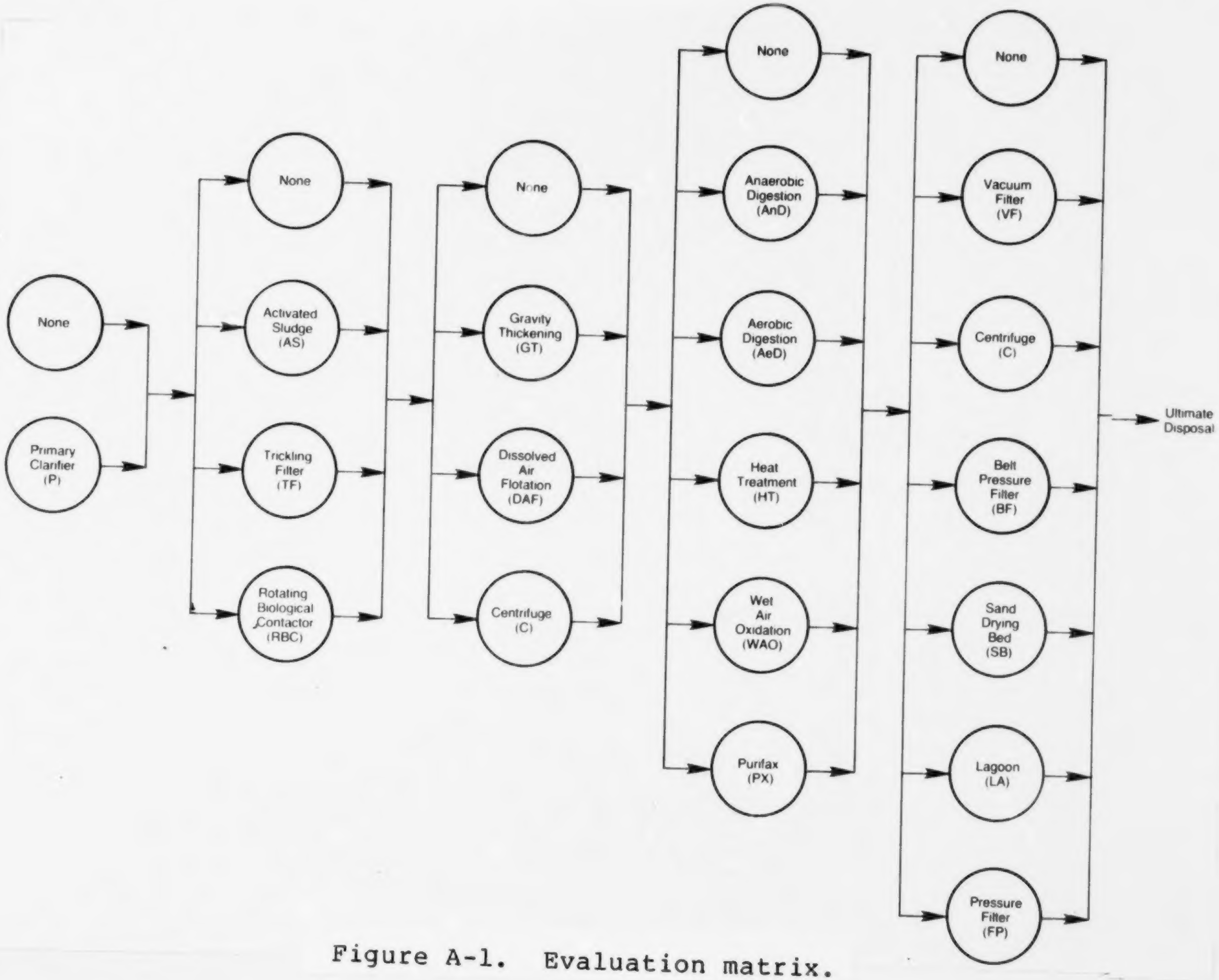
None
Primary Clarifier (P)
None
Activated Sludge (AS)
Trickling Filter (TF)
Rotating Biological Contactor (RBC)
None
Gravity Thickening (GT)
Dissolved Air Flotation (DAF)
Centrifuge (C)
None
Anaerobic Digestion (AnD)
Aerobic Digestion (AeD)
Heat Treatment (HT)
Wet Air Oxidation (WAO)
Purifax (PX)
None
Vacuum Filter (VF)
Centrifuge (C)
Belt Pressure Filter (BF)
Sand Drying Bed (SB)
Lagoon (LA)
Pressure Filter (FP)
Ultimate Disposal

Figure A-1. Evaluation matrix.

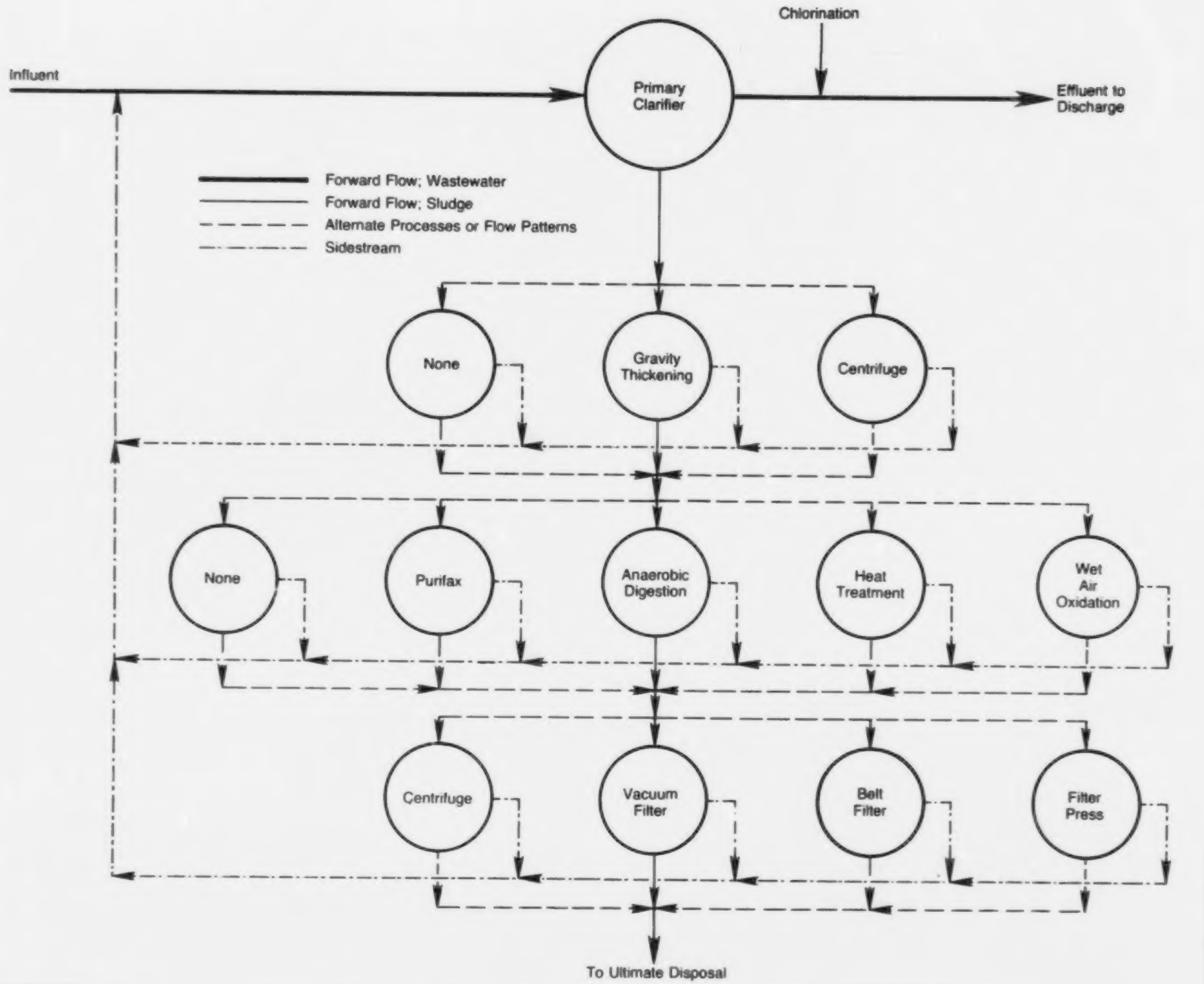
Influent
Primary Clarifier
Chlorination
Effluent to Discharge
Forward Flow; Wastewater
Forward Flow; Sludge
Alternate Processes or Flow Patterns
Sidestream
None
Gravity Thickening
Centrifuge
None
Purifax
Anaerobic Digestion
Heat Treatment
Wet Air Oxidation
Centrifuge
Vacuum Filter
Belt Filter
Filter Press
To Ultimate Disposal

Figure A-2. Typical primary treatment flow process schemes.

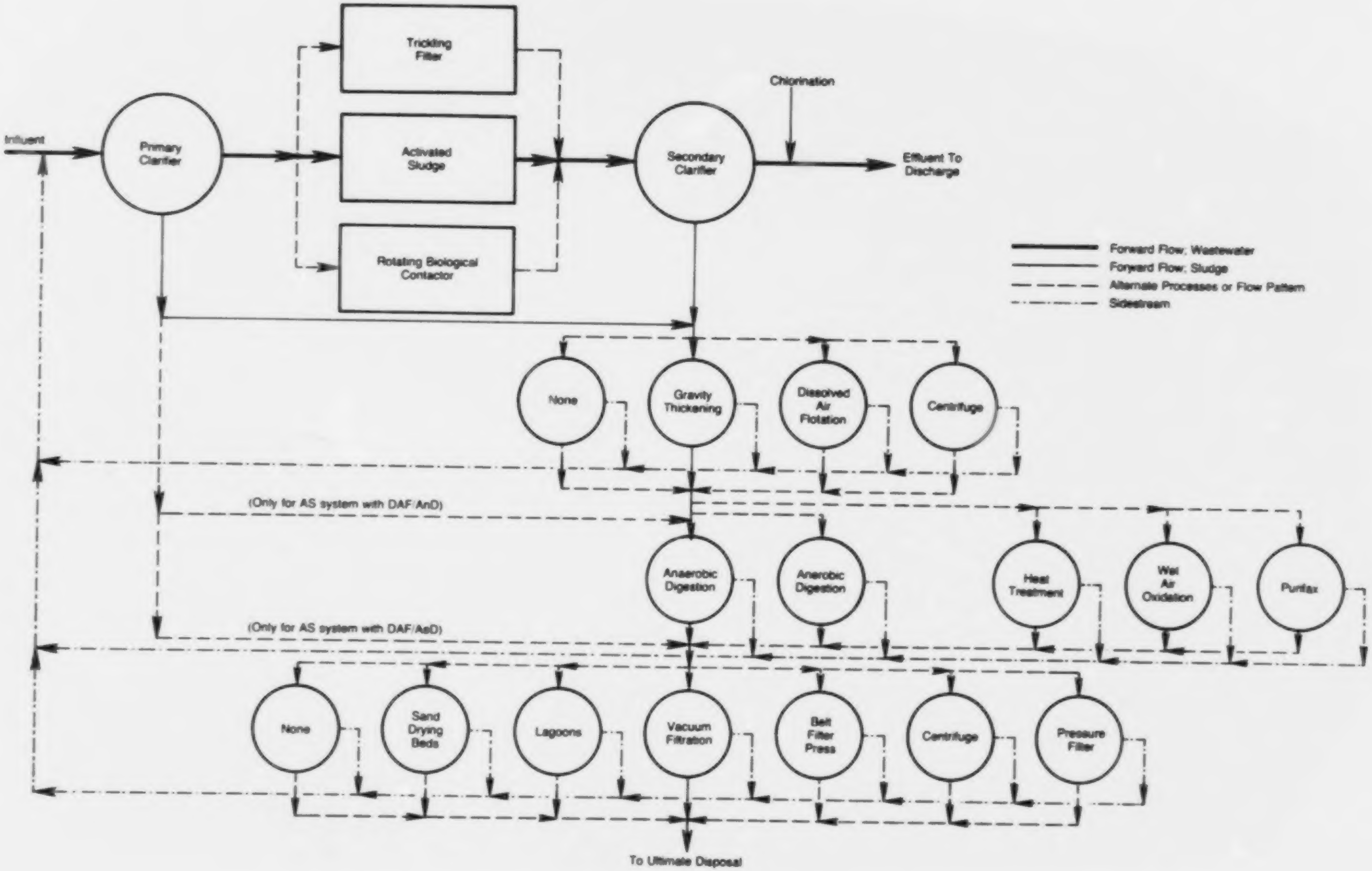
Influent
Primary Clarifier
Trickling Filter
Activated Sludge
Rotating Biological Contactor
Secondary Clarifier
Chlorination
Effluent To Discharge
Forward Flow, Wastewater
Forward Flow, Sludge
Alternate Processes or Flow Pattern
Sidestream
None
Gravity Thickening
Dissolved Air Flotation
Centrifuge
(Only for AS system with DAF/AnD)
Anaerobic Digestion
Anerobic Digestion
Heat Treatment
Wet Air Oxidation
Purifax
(Only for AS system with DAF/AeD)
None
Sand Drying Beds
Lagoons
Vacuum Filtration
Belt Filter Press
Centrifuge
Pressure Filter
To Ultimate Disposal

Figure A-3. Typical secondary treatment flow process schemes.

4. Gravity thickening was used with anaerobic digestion only; dissolved air flotation was used with both anaerobic and aerobic digestion.

5. Aerobic digestion was applicable to activated sludge processes only.

6. Primary sludge which received no treatment (AnD, HT, or WAO) prior to dewatering could be dewatered by only VF, C, BF, or FP.

This reduced the number of potentially different sidestreams which could be generated to 211.

RANKED MATRIX

This section presents the methodology used to determine characteristics and relative importance of the sidestreams and contains the following elements:

1. Models used for characterization.

2. Characterization of the sidestreams.

3. Equation utilized to determine relative importance (prioritization equation).

4. Ranking of the sidestreams.

A sidestream literature search was conducted to provide information and data required to complete the characterization and ranking. The resulting bibliography is included in this appendix.

Models

General--
The first step in the characterization/prioritization of the sidestreams was development of models. Two types of models were developed--graphical and mathematical. The graphical models were used to select the wastewater treatment process flow schemes to be evaluated. The mathematical models simulated types of treatment (physical and biological), and predicted effluent and underflow characteristics.

Graphical Models--
Three graphical models were developed. Figure A-4 is used for mainstream treatment processes using primary clarification only. Figures A-5 and A-6 are used for mainstream treatment

processes using activated sludge or trickling filter/rotating biological contactor systems, respectively. Through use of these models any wastewater treatment process flow scheme evaluated in this document can be derived.

Mathematical Models--

When the graphical models are analyzed it is apparent that they are composed of treatment processes/operations which can be subdivided into:

1. Primary clarification (P)

2. Secondary treatment

    - Activiated sludge (AS)
    - Trickling filter (TF)
    - Rotating biological contactor (RBC)

3. Sludge handling

    - Digestion

    - Anaerobic digestin (AnD)
    - Aerobic digestion (AeD)

    - Conditioning

    - Heat treatment (HT)
    - Wet air oxidation (WAO)
    - Purifax (PX)

    - Dewatering

    - Gravity thickening (GT)
    - Dissolved air flotation thickening (DAF)
    - Vacuum filtration (VF)
    - Centrifugation (C)
    - Belt filter press (BF)
    - Sand bed drying (SB)
    - Lagoon (LA)
    - Pressure filter (filter press) (FP)

Mathematical models were developed for P, AS, TF, RBC, digestion, conditioning, and dewatering categories. Parameters, coefficients, or constants common to all processes/operations are included with the model presentation; those which are not common are summarized in the subsection on characterization in Section 2.

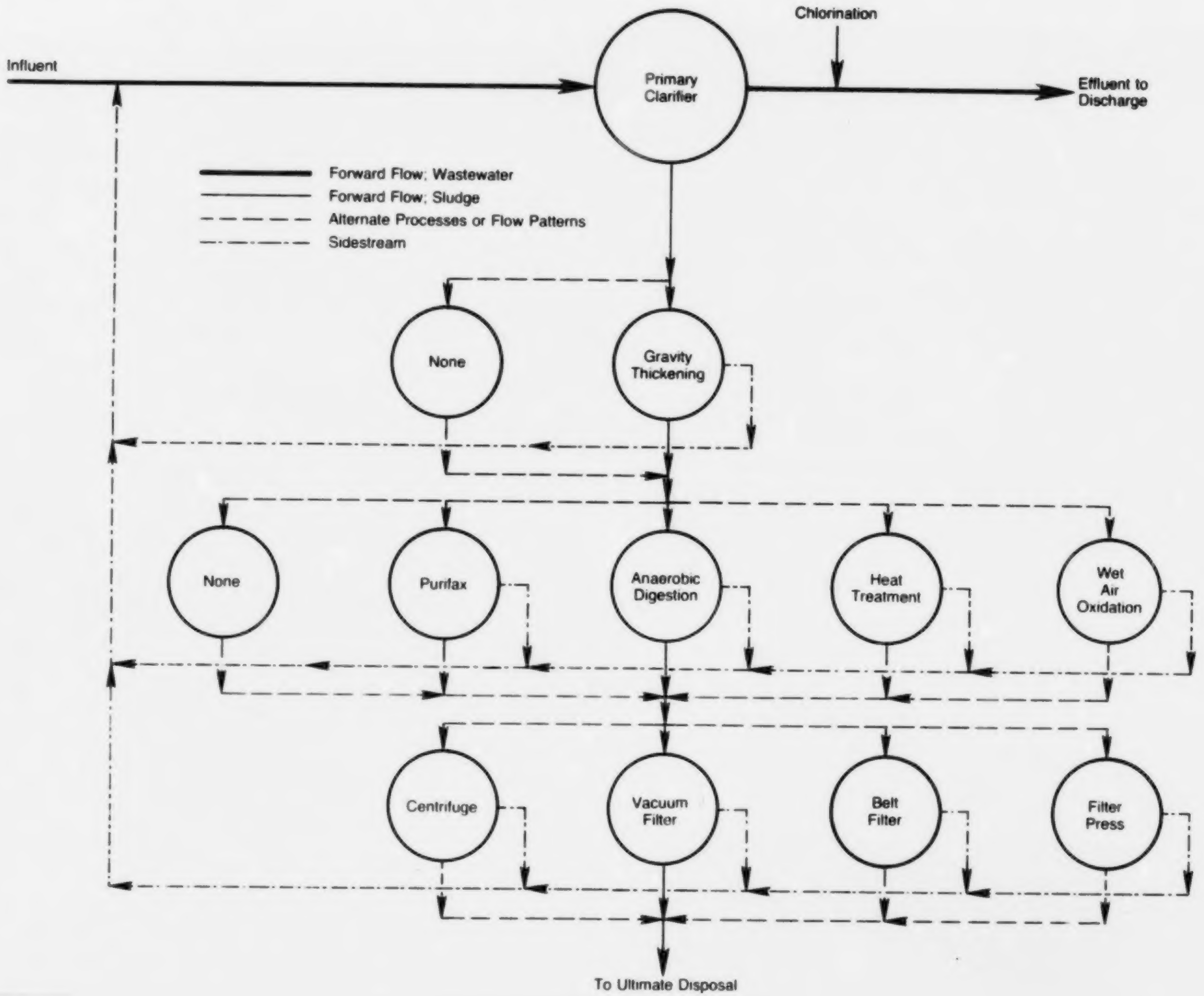
Influent
Primary Clarifier
Chlorination
Effluent to Discharge
Forward Flow; Wastewater
Forward Flow; Sludge
Alternate Processes or Flow Patterns
Sidestream
None
Gravity Thickening
None
Purifax
Anaerobic Digestion
Heat Treatment
Wet Air Oxidation
Centrifuge
Vacuum Filter
Belt Filter
Filter Press
To Ultimate Disposal

Figure A-4. Primary treatment model.

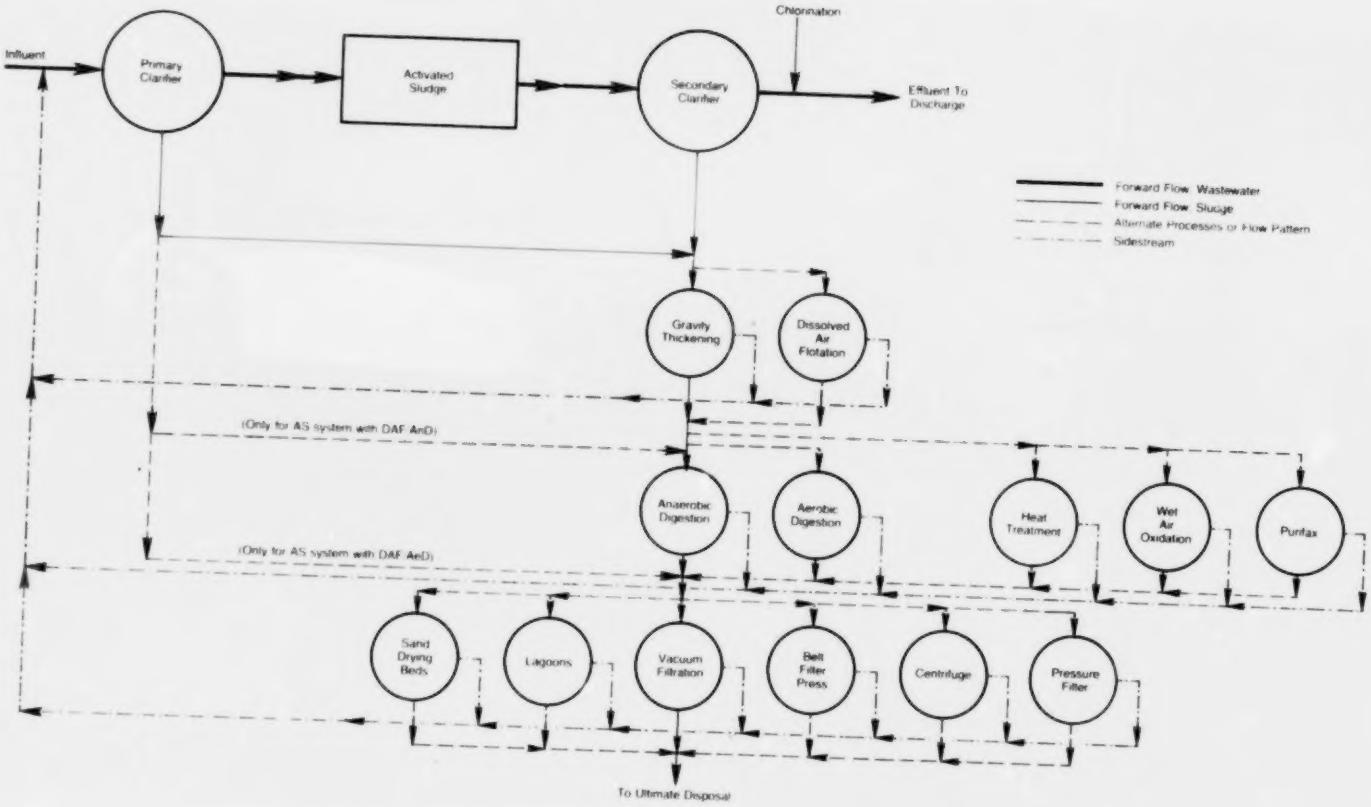
Influent
Primary Clarifier
Activated Sludge
Secondary Clarifier
Chlorination
Effluent To Discharge
Forward Flow Wastewater
Forward Flow Sludge
Alternate Processes or Flow Pattern
Sidestream
Gravity Thickening
Dissolved Air Flotation
(Only for AS system with DAF AnD)
Anaerobic Digestion
Aerobic Digestion
Heat Treatment
Wet Air Oxidation
Purifax
(Only for AS system with DAF AeD)
Sand Drying Beds
Lagoons
Vacuum Filtration
Belt Filter Press
Centrifuge
Pressure Filter
To Ultimate Disposal

Figure A-5. Activated sludge model.

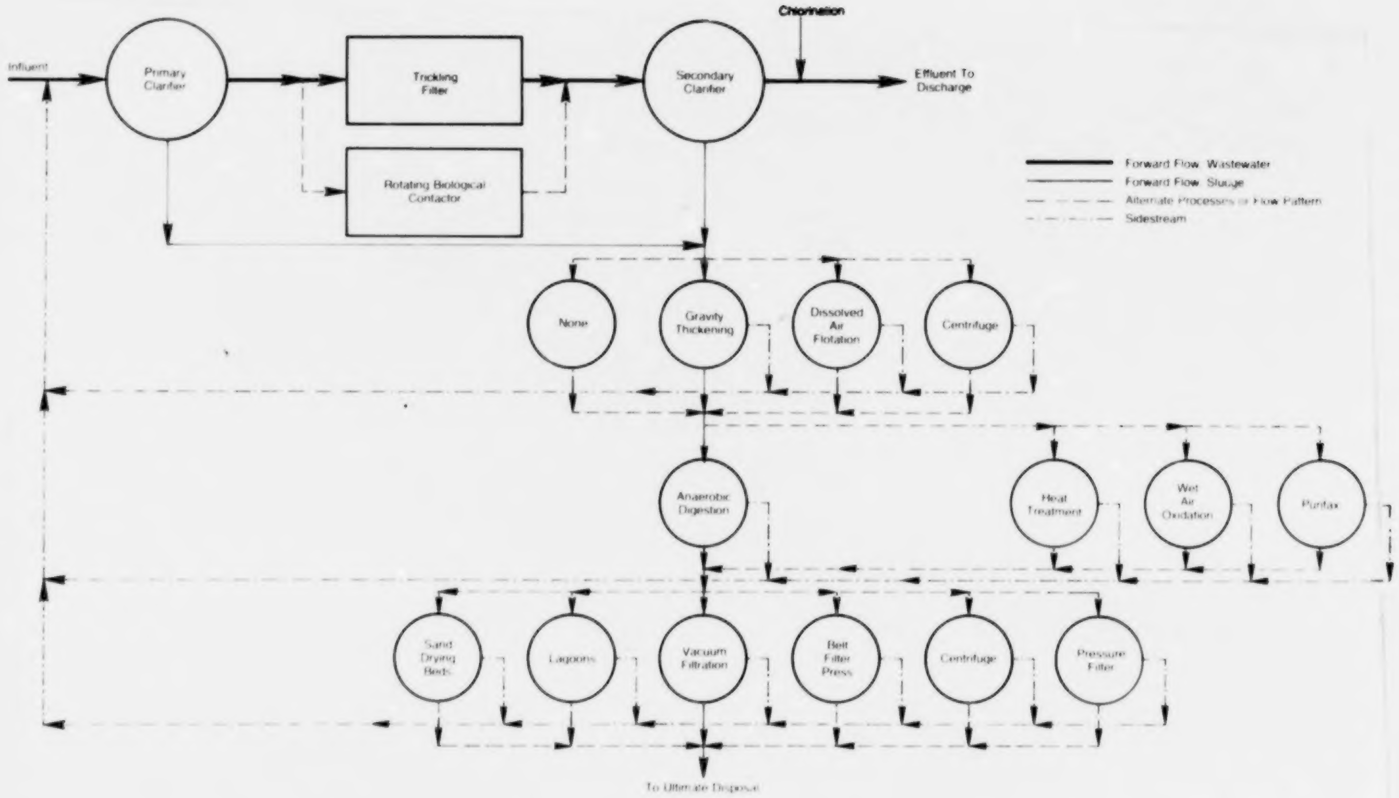
Influent
Primary Clarifier
Trickling Filter
Rotating Biological Contactor
Secondary Clarifier
Chlorination
Effluent To Discharge
Forward Flow Wastewater
Forward Flow Sludge
Alternate Processes or Flow Pattern
Sidestream
None
Gravity Thickening
Dissolved Air Flotation
Centrifuge
Anaerobic Digestion
Heat Treatment
Wet Air Oxidation
Purifax
Sand Drying Beds
Lagoons
Vacuum Filtration
Belt Filter Press
Centrifuge
Pressure Filter
To Ultimate Disposal

Figure A-6. Trickling filter/RBC model.

For all models, the notation utilized is:

1. Subscript o (e.g., TSS_o) represents influent characteristics to the process/operation being modeled; for example, wastewater to the primary clarifier, thickened sludge to a digester, digested sludge to a vacuum filter, etc.
2. Subscript e (e.g., TSS_e) represents effluent characteristics from the process/operation being modeled; for example, thickened sludge from dissolved air flotation, digested sludge from anaerobic digestion, dewatered sludge from a centrifuge, etc.

Influent--Characteristics of the wastewater to the POTW are an important consideration because those characteristics, in conjunction with the wastewater treatment process flow scheme, determine the quantities and characteristics of sludges and subsequent sidestreams produced by the processes/operations. For this document, the wastewater was assumed to be normal, possessing no unusual characteristics or significant industrial contributors.

Parameters which were considered in this document were flow (Q), five-day biochemical oxygen demand (BOD_5), and suspended solids (SS). The influent flow (sidestream recycle not included) was set at one million gallons per day (mgd). This enables the user to take any data presented in later sections and apply it to his existing or proposed POTW by multiplying those values of interest by his flow in mgd (e.g., for a flow at 10 mgd multiply by 10 and for a flow of 0.5 mgd multiply by 0.5). Total five-day biochemical oxygen demand ($TBOD_5$) was divided into two categories: the dissolved, or soluble, fraction ($DBOD_5$), assumed to be 35 percent of the $TBOD_5$ (34); and, the BOD_5 associated with the solids ($SBOD_5$), assumed to be 65 percent of the $TBOD_5$. Total suspended solids (TSS) was divided into two major categories: fixed (nondegradable) solids (FSS), assumed to be 25 percent of the TSS (75); and, the volatile suspended solids (VSS), assumed to be 75 percent of the TSS. The volatile suspended solids were further subdivided into three categories; those associated with the biomass (X), assumed to be 0 percent in the influent; those which could be degraded in five days or less by a microbial population, the biodegradable VSS (BVSS), assumed to be 67 percent of the VSS (101); and, those which could not be degraded in five days or less by a microbial population, the refractory VSS (RVSS), assumed to be 33 percent of the VSS (101).

In summary, the characteristics of the influent wastewater were:

● Q	1 mgd
● $TBOD_5$	220 mg/L
- $DBOD_5$	77 mg/L
- $SBOD_5$	143 mg/L
● TSS	220 mg/L
- FSS	55 mg/L
- X	0 mg/L
- BVSS	110 mg/L
- RVSS	55 mg/L

Primary Clarification--Sedimentation is an operation where change is brought about through the application of physical forces and material is neither gained nor lost. Sedimentation is effected in the primary clarifier and is the separation of suspended particles, which are heavier than water, from the water. The following equations make up the primary clarification model and are used in the order in which they appear:

Influent

$$Q_o = 1,000,000 + Q_{ss} \qquad \text{gpd} \qquad \text{(A-1)}$$

$$DBOD_{5o} = 642 + DBOD_{5ss} \qquad \text{lbs/day} \qquad \text{(A-2)}$$

$$SBOD_{5o} = 1193 + SBOD_{5ss} \qquad \text{lbs/day} \qquad \text{(A-3)}$$

$$FSS_o = 459 + FSS_{ss} \qquad \text{lbs/day} \qquad \text{(A-4)}$$

$$X_o = 0 + X_{ss} \qquad \text{lbs/day} \qquad \text{(A-5)}$$

$$BVSS_o = 917 + BVSS_{ss} \qquad \text{lbs/day} \qquad \text{(A-6)}$$

$$RVSS_o = 459 + RVSS_{ss} \qquad \text{lbs/day} \qquad \text{(A-7)}$$

$$TBOD_5 = DBOD_5 + SBOD_5 \qquad \text{lbs/day} \qquad \text{(A-8)}$$

$$TSS = FSS + X + BVSS + RVSS \qquad \text{lbs/day} \qquad \text{(A-9)}$$

Underflow

$$TSS_u = a\ TSS_o \qquad \text{lbs/day} \qquad \text{(A-10)}$$

$$FSS_u = \frac{(FSS_o)}{(TSS_o)}\ TSS_u \qquad \text{lbs/day} \qquad \text{(A-11)}$$

$$X_u = \frac{(X_o)}{(TSS_o)} TSS_u \qquad \text{lbs/day} \qquad \text{(A-12)}$$

$$BVSS_u = \frac{(BVSS_o)}{(TSS_o)} TSS_u \qquad \text{lbs/day} \qquad \text{(A-13)}$$

$$RVSS_u = \frac{(RVSS_u)}{(TSS_o)} TSS_u \qquad \text{lbs/day} \qquad \text{(A-14)}$$

$$Q_u = \frac{TSS_u}{(c)\ (3.34)} (10^6) \qquad \text{gpd} \qquad \text{(A-15)}$$

Concentration $DBOD_{5u}$

$$DBOD_{5o} = \frac{DBOD_{5o}}{(Qo)\ (8.34)} \quad \frac{\text{lbs/day}}{\text{mgd}} \qquad \text{mg/L} \qquad \text{(A-16)}$$

$$DBOD_{5u} = \underset{\text{(mg/L)}}{(DBOD_{5o})}\ \underset{\text{(mgd)}}{(Q_u)}\ (8.34) \qquad \text{lbs/day} \qquad \text{(A-17)}$$

$$SBOD_{5u} = bTBOD_{5o} - DBOD_{5u} \qquad \text{lbs/day} \qquad \text{(A-18)}$$

Effluent

$$Q_c = Q_o - Q_u \qquad \text{gpd} \qquad \text{(A-19)}$$

$$DBOD_{5e} = DBOD_{5o} - DBOD_{5u} \qquad \text{lbs/day} \qquad \text{(A-20)}$$

$$SBOD_{5e} = SBOD_{5o} - SBOD_{5u} \qquad \text{lbs/day} \qquad \text{(A-21)}$$

$$FSS_e = FSS_o - FSS_u \qquad \text{lbs/day} \qquad \text{(A-22)}$$

$$X_e = X_o - X_u \qquad \text{lbs/day} \qquad \text{(A-23)}$$

$$BVSS_e = BVSS_o - BVSS_u \qquad \text{lbs/day} \qquad \text{(A-24)}$$

$$RVSS_e = RVSS_o - RVSS_u \qquad \text{lbs/day} \qquad \text{(A-25)}$$

Where:

subscript o = influent (with sidestream recycle)
subscript ss= sidestream recycle
subscript u = underflow
subscript e = effluent
a = percent TSS removed by sedimentation
b = percent $TBOD_5$ removed by sedimentation

Activated Sludge--For modeling purposes a complete mix activated sludge model (34) was adopted. There are many other types of activated sludge systems available and, while the results should be similar, it may be necessary to use a different model to accurately predict them.

The activated sludge system uses a suspended growth of microorganisms in a reactor to convert the colloidal and dissolved carbonaceous organic matter into various gases and cell tissue. Removal of the cell tissue is effected in a secondary clarifier. Since this is a biological process material is destroyed and created.

The following equations make up the activated sludge model and are used in the order in which they appear:

Influent is the effluent from the primary clarifier.

$$DBOD_{5e} = \frac{Ks(1+bQc)}{Qc(Yk-b)-1} \quad \text{mg/L} \qquad (A-26)$$

$$X_r = \frac{Y(S_o - S_1)}{1 + bQ_c} \frac{(Qc)}{(Q\ )} \quad \text{mg/L} \qquad (A-27)$$

$$RVSS_r = RVSS_o \frac{(Qc)}{(Q\ )} + gbQcX_r + 0.23X_o \quad \text{mg/L} \qquad (A-28)$$

$$FSS_r = FSS_o \frac{(Qc)}{(Q\ )} + dX_r + 0.11X_o \quad \text{mg/L} \qquad (A-29)$$

$$TSS_w = [X_r + RVSS_r] \left[\frac{1 + R - \frac{(Q\ )}{(Qc)}}{R} \right] \text{mg/L} \qquad (A-30)$$

$$Q_w = Q_o \left[\frac{TSS_r(1+R) - TSS_e - TSS_w R}{TSS_w - TSS_e}\right] \text{gpd} \qquad \text{(A-31)}$$

Reactor

$$Q_r = Q_o + RQ_o \qquad \text{gpd} \qquad \text{(A-32)}$$

$$DBOD_{5r} = DBOD_{5c}\ (Q_r)\ (8.34) \qquad \text{lbs/day} \qquad \text{(A-33)}$$

(mg/L) (mgd)

$$SBOD_{5r} = X_r \qquad \text{lbs/day} \qquad \text{(A-34)}$$

$$FSS_r = FSS_r(Q_r)\ (8.34) \qquad \text{lbs/day} \qquad \text{(A-35)}$$

(mg/L) (mgd)

$$X_r = X_r(Q_r)\ (8.34) \qquad \text{lbs/day} \qquad \text{(A-36)}$$

(mg/L) (mgd)

$$BVSS_r = BVSS_r(Q_r)\ (8.34) \qquad \text{lbs/day} \qquad \text{(A-37)}$$

(mg/L) (mgd)

$$RVSS_r = RVSS_r(Q_r)\ (8.34) \qquad \text{lbs/day} \qquad \text{(A-38)}$$

(mg/L) (mgd)

Recycle Flow

$$Q_{rc} = RQ_o \qquad \text{gpd} \qquad \text{(A-39)}$$

Sludge Wasted

$$Q_w = \text{See 4-31} \qquad \text{gpd}$$

$$TSS_w = TSS_w(Q_w)\ (8.34) \qquad \text{lbs/day} \qquad \text{(A-40)}$$

(mg/L) (mgd)

$$FSS_w = TSS_w \left(\frac{FSS_r}{TSS_r}\right) \qquad \text{lbs/day} \qquad \text{(A-41)}$$

$$X_w = TSS_w \left(\frac{X_r}{TSS_r}\right) \qquad \text{lbs/day} \qquad \text{(A-42)}$$

$$BVSS_w = TSS_w \left(\frac{BVSS_r}{TSS_r}\right) \qquad \text{lbs/day} \qquad \text{(A-43)}$$

$$RVSS_w = TSS_w \left(\frac{RVSS_r}{TSS_r}\right) \qquad \text{lbs/day} \qquad (A\text{-}44)$$

$$DBOD_{5w} = \underset{(mg/L)}{DBOD_{5e}}\underset{(mgd)}{(Qw)}\ (8.34) \qquad \text{lbs/day} \qquad (A\text{-}45)$$

$$SBOD_{5w} = X_w \qquad \text{lbs/day} \qquad (A\text{-}46)$$

Underflow

$$Q_u = Q_{rc} + Q_w \qquad \text{gpd} \qquad (A\text{-}47)$$

$$TSS_u = \underset{(mg/L)}{TSS_w}\underset{(mgd)}{(Q_u)}\ (8.34) \qquad \text{lbs/day} \qquad (A\text{-}48)$$

$$FSS_u = TSS_u \left(\frac{FSS_r}{TSS_r}\right) \qquad \text{lbs/day} \qquad (A\text{-}49)$$

$$X_u = TSS_u \left(\frac{X_r}{TSS_r}\right) \qquad \text{lbs/day} \qquad (A\text{-}50)$$

$$BVSS_u = TSS_u \left(\frac{BVSS_r}{TSS_r}\right) \qquad \text{lbs/day} \qquad (A\text{-}51)$$

$$RVSS_u = TSS_u \left(\frac{RVSS_r}{TSS_r}\right) \qquad \text{lbs/day} \qquad (A\text{-}52)$$

$$DBOD_{5u} = \underset{(mg/L)}{(DBOD_{5e})}\ \underset{(mgd)}{(Q_u)}\ (8.34) \qquad \text{lbs/day} \qquad (A\text{-}53)$$

$$SBOD_{5u} = X_u \qquad \text{lbs/day} \qquad (A\text{-}54)$$

Effluent

$$Q_e = Q_o - Q_u \qquad \text{gpd} \qquad (A\text{-}55)$$

$$DBOD_{5e} = DBOD_{5o} - DBOD_{5u} \qquad \text{lbs/day} \qquad (A\text{-}56)$$

$$SBOD_{5e} = SBOD_{5o} - SBOD_{5u} \qquad \text{lbs/day} \qquad (A\text{-}57)$$

$$FSS_e = FSS_o - FSS_u \qquad \text{lbs/day} \qquad (A\text{-}58)$$

$$X_e = X_o - X_u \quad \text{lbs/day} \quad \text{(A-59)}$$

$$BVSS_e = BVSS_o - BVSS_u \quad \text{lbs/day} \quad \text{(A-60)}$$

$$RVSS_e = RVSS_o - RVSS_u \quad \text{lbs/day} \quad \text{(A-61)}$$

Where:

subscript o = influent (primary clarifier effluent)
subscript e = effluent
subscript r = reactor (aeration basin)
subscript w = waste sludge
subscript rc = sludge return
subscript u = sludge underflow (secondary clarifier)
k = maximum rate of substrate removal per unit of biomass
= 5.0 days^{-1}
ks = substrate concentration at which removal rate is k/2
= 60 mg/L
y = yield coefficient = 0.6 mgVSS/mgBOD_5
b = fractional decay rate = 0.06 days^{-1}
g = substrate that cannot be broken down within mean cell residence time
= 0.23
d = ratio of fixed to volatile microbial mass = 0.11
Q_C= sludge age = 6 days
Q = hydraulic retention time = 6 hours; 9.25 days
R = recycle rate = 0.5; 50 percent

Trickling Filter--For modeling purposes a trickling filter model was developed which included recycle. The trickling filter system uses microorganisms, attached to a fixed media (usually rock or plastic), to convert the colloidal and dissolved carbonaceous organic matter into various gases and cell tissue. The wastewater is passed or trickled through this media. Removal of sloughed solids and various other solids is effected in a secondary clarifier. Since this is a biological process material is destroyed and created.

The following equations make up the trickling filter model and are used in the order in which they appear.

Influent is the effluent from the primary clarifier plus any recycle.

$DBOD_{5_o}$ goes to 0.0; $DBOD_{5_e} = DBOD_{5_u}$ (A-62)

= 0.0 lbs/day

X_1 biomass generated by destruction $DBOD_{5_c}$ (A-63)

= Y $(DBOD_{5_o})$ lbs/day

$SBOD_{5_o}$ goes to 0.0 lbs/day (A-64)

X_2 biomass generated by destruction $SBOD_{5_o}$ (A-65)

= Y $(SBBOD_{5_o})$ lbs/day

$FSS_o = FSS_e + FSS_u$ lbs/day (A-66)

$BVSS_o$ goes to 0.0; $BVSS_e = BVSS_u$ (A-67)

= 0.0 lbs/day

X_3 biomass generated by destruction $BVSS_e$ (A-68)

alreay accounted for in X_2

$RVSS_u + RVSS_e = (a)\ (RVSS_o) = Y\ (1-a)\ (RVSS_o)$ lbs/day

X_4 biomass generated by destruction $RVSS_o$ (A-69)

= $Y\ (1-a)\ (RVSS_o)$ lbs/day

$X_u + X_e = X_1 + X_2 + X_4$ lbs/day (A-70)

$$Q_u = Q_o \frac{C_o - C_e}{C_u - C_e} \text{ gpd} \qquad \text{(A-71)}$$

$$Q_e = Q_o - Q_u \qquad \text{(A-72)}$$

Reactor

$Q_{re} = Q_o = Q_e + Q_u$ gpd (A-73)

$DBOD_{5_{re}} = 0.0$ lbs/day (A-74)

$SBOD_{5_{re}} = X_u + X_e = X_1 + X_2 + X_4$ lbs/day (A-75)

$FSS_{re} = FSS_o$ lbs/day (A-76)

$X_{re} = X_u + X_e = X_1 + X_2 + X_4$ lbs/day (A-77)

$VSS_{re} = 0.0$ lbs/day (A-78)

$RVSS_{re} = RVSS_u + RVSS_e = a\ (RVSS_o)$ lbs/day (A-79)

$TSS_{re} = FSS_{re} + X_{re} + BVSS_{rc} + RVSS_{re}$ lbs/day (A-80)

Underflow

Q_u See equation (A-71)

$DBOD_{5_u}$ See (A-62)

$SBOD_{5_u} = X_u$ See (A-84) lbs/day (A-81)

$TSS_u = (C_1)\ (Q_u)\ (8.34)$ (A-82)

(mg/L) (mgd) lbs/day

$FSS_u = TSS_u \left(\frac{FSS_{re}}{TSS_{re}}\right)$ lbs/day (A-83)

$X_u = TSS_u \left(\frac{X_{re}}{TSS_{re}}\right)$ lbs/day (A-84)

$BVSS_u$ See (A-67)

$RVSS_u = TSS_u \left(\frac{RVSS_{re}}{TSS_{re}}\right)$ lbs/day (A-85)

Effluent

Q_e See (A-72)

$DBOD_{5_e}$ See (A-62)

$SBOD_{5_e} = X_e$ See (A-88) lbs/day (A-86)

$$FSS_e = FSS_{re} - FSS_u \text{ lbs/day} \tag{A-87}$$

$$X_e = X_{re} - X_u \text{ lbs/day} \tag{A-88}$$

$$BVSS_e = BVSS_{re} - BVSS_u \text{ lbs/day} \tag{A-89}$$

$$RVSS_e = RVSS_{re} - RVSS_u \text{ lbs/day} \tag{A-90}$$

Where:

subscript o = influent (primary clarifier effluent plus any recycle)

subscript e = effluent

subscript u = under flow (secondary clarifier)

subscript re = reactor

Y = yield factor
lbs x generated per lb of material destroyed = 0.2

a = percent of material oxidized by system
= 0.543

Rotating Biological Contactor (RBC)--For modeling purposes an RBC model was developed. The RBC system uses microorganisms, attached to a plastic (polystyrene or polyvinyl chloride) disc, to convert the colloidal and dissolved carbonaceous organic matter into various gases and cell tissue.

A series of these closely spaced discs are partially submerged in the wastewater and rotated slowly through it. Removal of sloughed and miscellaneous solids is effected in a secondary clarifier. Since this is a biological process, material is destroyed and created.

The following equations make up the RBC model and are used in the order in which they appear to complete the steady-state mass balance.

Influent is the effluent from the primary clarifier.

$$TBOD_{5_o} = DBOD_{5_o} + SBOD_{5_o} \quad \text{lbs/day} \quad \text{(A-91)}$$

$$TBOD_{5_{re}} = (a)\ (TBOD_{5_o}) \quad \text{lbs/day} \quad \text{(A-92)}$$

$$DBOD_{5_{re}} = (b)\ (DBOD_{5_o}) \quad \text{lbs/day} \quad \text{(A-93)}$$

$$SBOD_{5_{re}} = TBOD_{5_{re}} - DBOD_{5_{re}} \quad \text{lbs/day} \quad \text{(A-94)}$$

$$RVSS_{re} = 100 \quad \text{lbs/day} \quad \text{(A-95)}$$

X_1 biomass generated by destruction $RVSS_o$ (A-96)

$= Y\ (RVSS_o - 100)$ lbs/day

X_2 biomass generated by destruction $DBOD_{5_e}$ (A-97)

$= Y\ (1-b)\ (DBOD_{5_o})$ lbs/day

X_3 biomass generated by destruction $SBOD_{5_o}$ (A-98)

$= Y\ (SBOD)_{5_o} - SBOD_{5_{re}})$ lbs/day

$$X_{re} = X_1 + X_2 + X_3 \ \text{lbs/day} \quad \text{(A-99)}$$

$$SBOD_{5_{re}} = X_{re} \ \text{lbs/day} \quad \text{(A-100)}$$

$$BVSS_{re} = \frac{TBOD_{re} - SBOD_{5_{re}} \ \text{(due to } X_{re})}{R} \quad \text{lbs/day} \quad \text{(A-101)}$$

$$R = \frac{SBOD_{5_o}}{BVSS_o} \quad \text{(A-102)}$$

$$Q_u = Q_o \left[\frac{C_o - C_e}{C_u - C_e}\right] \text{gpd} \quad \text{(A-103)}$$

$$Q_e = Q_o - Q_u \quad \text{gpd} \qquad \text{(A-104)}$$

$$Q_{re} = Q_o \quad \text{gpd} \qquad \text{(A-105)}$$

$$TSS_{re} = FSS_{re} + X_{re} + BVSS_{re} + RVSS_{re} \quad \text{lbs/day} \qquad \text{(A-106)}$$

$$DBOD_{5_{re}} = \frac{DBOD_{5_{re}}}{(8.34)\ (Q_{re})} \quad \frac{\text{lbs/day}}{\text{mgd}} \quad \text{mg/L} \qquad \text{(A-107)}$$

Underflow

Q_u See (4-103)

$$DBOD_{5_u} = (DBOD_{5_{re}})\ (Q_u)\ (8.34) \qquad \text{(A-108)}$$

(mg/L) (mgd) lbs/day

$$SBOD_{5_u} = X_u + (BVSS_u)\ (R) \quad \text{See (4-112)} \qquad \text{(A-109)}$$

and (4-113) lbs/day

$$TSS_u = (C_u)\ (Q_u)\ (8.34) \qquad \text{(A-110)}$$

(mg/L) (mgd) lbs/day

$$FSS_u = TSS_u \left(\frac{FSS_{re}}{TSS_{re}}\right) \quad \text{lbs/day} \qquad \text{(A-111)}$$

$$X_u = TSS_u \left(\frac{X_{re}}{TSS_{re}}\right) \quad \text{lbs/day} \qquad \text{(A-112)}$$

$$BVSS_u = TSS_u \left(\frac{BVSS_{re}}{TSS_{re}}\right) \quad \text{lbs/day} \qquad \text{(A-113)}$$

$$BVSS_u = TSS_u \left(\frac{BVSS_{re}}{TSS_{re}}\right) \text{lbs/day} \qquad \text{(A-114)}$$

Effluent

$$DBOD_{5_e} = DBOD_{5_{re}} - DBOD_{5_u} \quad \text{lbs/day} \qquad \text{(A-115)}$$

$$SBOD_{5_e} = SBOD_{5_{re}} - SBOD_{5_u} \quad \text{lbs/day} \qquad \text{(A-116)}$$

$$FSS_e = FSS_{re} - FSS_u \quad \text{lbs/day} \qquad \text{(A-117)}$$

$$X_e = X_{re} - X_u \text{ lbs/day} \quad \text{(A-118)}$$

$$BVSS_e = BVSS_{re} - BVSS_u \text{ lbs/day} \quad \text{(A-119)}$$

$$RVSS_e = RVSS_{re} - RVSS_u \text{ lbs/day} \quad \text{(A-120)}$$

Where:

subscript o = influent (primary clarifier effluent)
subscript e = effluent
subscript u = underflow
subscript re = reactor
Y = yield factor lbs x generated per lb of material destroyed = 0.2

a = percent $TBOD_{5_o}$ removed = 0.25

b = percent $DBOD_{5_o}$ removed = 0.08

C_o = concentration TSS_o

C_e = concentration TSS_e

C_u = concentration TSS_u

Anaerobic Digestion--For modeling purposes an anaerobic digestion model (34) was adopted.

Anaerobic digestion is a process utilized to stabilize sludges. It involves the decomposition of organic and inorganic matter in the absence of molecular oxygen. The stabilized sludge is nonputrescible and has a reduced pathogen content. Byproducts are methane and carbon diozide.

The following equations make up the anaerobic digestion model and are used in the order in which they appear.

Influent is the thickened sludge from gravity thickeners or dissolved air flotation units.

$$Q_u = aQ_o \quad \text{gpd} \tag{A-121}$$

$$Q_e = Q_o - Q_u \quad \text{gpd} \tag{A-122}$$

$$DBOD_{5_{re}} = \frac{K_c\ (1+b\theta_c)}{\theta_c(Ym\ Km-b)-1} \quad \text{mg/L} \tag{A-123}$$

$$X_{re} = \frac{Y_a\ (TBOD_o + Ym\ (TBOD_o - DBOD_{re})}{1+b0_c} \quad \text{mg/L} \tag{A-124}$$

$$FSS_{re} = FSS_o + fX_{re} + fX_o \quad \text{mg/L} \tag{A-125}$$

$$RVSS_{re} = \frac{RVSS_o + gX_o + gb\theta_c X_{re}}{1+d0_c} \quad \text{mg/L} \tag{A-126}$$

$$BVSS_{re} = 0 \quad \text{mg/L} \tag{A-127}$$

$$SBOD_{5_{re}} = X_{re} \quad \text{mg/L} \tag{A-128}$$

Reactor

$$FSS_{re} = (RSS_{re})\ (Q_{re})\ (8.34) \tag{A-129}$$

(mg/L) (mgd) lbs/day

$$X_{re} = (X_{re})\ (Q_{re})\ (8.34) \tag{A-130}$$

(mg/L) (mgd) lbs/day

$$BVSS_{re} = (BVSS_{re})\ (Q_{re})\ (8.34) \tag{A-131}$$

(mg/L) (mgd) lbs/day

$$RVSS_{re} = (RVSS_{re})\ (Q_{re})\ (8.34) \tag{A-132}$$

(mg/L) (mgd) lbs/day

$$TSS_{re} = FSS_{re} + X_{re} + BVSS_{re} + RVSS_{re} \quad \text{lbs/day} \tag{A-133}$$

$$TSS_e = (c)\ (Q_{re})\ (8.34) \tag{A-134}$$

(mg/L) (mgd) lbs/day

$$FSS_e = TSS_e \left(\frac{FSS_{re}}{TSS_{re}}\right) \text{ lbs/day} \quad \text{(A-135)}$$

$$X_e = TSS_e \left(\frac{X_{re}}{TSS_{re}}\right) \text{ lbs/day} \quad \text{(A-136)}$$

$$BVSS_e = TSS_e \left(\frac{BVSS_{re}}{TSS_{re}}\right) \text{ lbs/day} \quad \text{(A-137)}$$

$$RVSS_e = TSS_e \left(\frac{RVSS_{re}}{TSS_{re}}\right) \text{ lbs/day} \quad \text{(A-138)}$$

$$DBOD_{5_e} = (DBOD_{5_{re}})\ (Q_e)\ (8.34) \quad \text{(A-139)}$$

$$\text{(mg/L)} \quad \text{(mgd)} \qquad \text{lbs/day}$$

$$SBOD_{5_e} = X_e \text{ lbs/day} \quad \text{(A-140)}$$

Underflow

$$FSS_u = FSS_{re} - FSS_e \text{ lbs/day} \quad \text{(A-141)}$$

$$X_u = X_{re} - X_e \text{ lbs/day} \quad \text{(A-142)}$$

$$BVSS_u = BVSS_{re} - BVSS_e \text{ lbs/day} \quad \text{(A-143)}$$

$$RVSS_u = RVSS_{re} - RVSS_e \text{ lbs/day} \quad \text{(A-144)}$$

$$DBOD_{5_u} = (DBOD_{5_{re}})\ (Q_u)\ (8.34) \quad \text{(A-145)}$$

$$\text{(mg/L)} \quad \text{(mgd)} \qquad \text{lbs/day}$$

$$SBOD_{5_u} = X_u \text{ lbs/day} \quad \text{(A-146)}$$

Where:

subscript o = influent (thickened sludge)
subscript re = reactor
subscript e = effluent
subscript u = underflow
a = ratio of underflow rate to feed flow rate = 0.6
c = concentration (mg/L) TSS_e

K_c = composite half-velocity kinetic coefficient = 1,500

b = fractional biomass decay rate = $0.02\ \text{day}^{-1}$

Y_m = biomass produced per unit mass of substrate used = 0.075

K_m = $4.4\ \text{day}^{-1}$

Y_a = biomass produced per unit mass of substrate used = 0.15

f = ratio of fixed to volatile solids = 0.11

g = fraction of decayed biomass remaining = 0.23

d = fractional RVSS decay rate = $0.01\ \text{day}^{-1}$

θ_c = sludge age = 25 days

Aerobic Digestion--For modeling purposes an aerobic digestion model (34) was adopted.

Aerobic digestion is a process used to stabilize sludges. The process is basically an extension of the activated sludge process where the feed is some type of thickened sludge, usually waste activated or combined primary/secondary. The process is in the endogenous phase. The microorganisms are oxidized aerobically to carbon dioxide, water, and ammonia, the ammonia subsequently being oxidized to nitrate.

The following equations make up the aerobic digestion model and are used in the order in which they appear.

Influent is the thickened sludge from gravity thickeners or dissolved air flotation units.

$$A_u = hQ_o \quad \text{gpd} \qquad \text{(A-147)}$$

$$Q_e = Q_o - Q_u \quad \text{gpd} \qquad \text{(A-148)}$$

$$DBOD_{5_{re}} = \frac{K_s\ (1+b\theta_c)}{\theta_c\ (Yk-b)-1} \qquad \text{(A-149)}$$

$$X_{re} = \frac{X_o + Y\ (TBOD_{5_o} - pX_o - DBOD_{5_{re}})}{1+b\theta_c} \quad \text{mg/L} \qquad \text{(A-150)}$$

$$FSS_{re} = FSS_o + fX_o + fX_{re} \quad mg/L \tag{A-151}$$

$$RVSS_{re} = \frac{RVSS_o + ab\theta_c X_{re}}{1+d\theta_c} \quad mg/L \tag{A-152}$$

$$BVSS_{re} = 0 \tag{A-153}$$

$$SBOD_{5_{re}} = X_{re} \quad mg/L \tag{A-154}$$

Reactor

$$FSS_{re} = (FSS_{re})\ (Q_{re})\ (8.34) \tag{A-155}$$

(mg/L) (mgd) lbs/day

$$X_{re} = (X_{re})\ (Q_{re})\ (8.34) \tag{A-156}$$

(mg/L) (mgd) lbs/day

$$BVSS_{re} = (BVSS_{re})\ (Q_{re})\ (8.34) \tag{A-157}$$

(mg/L) (mgd) lbs/day

$$RVSS_{re} = (RVSS_{re})\ (Q_{re})\ (8.34) \tag{A-158}$$

(mg/L) (mgd) lbs/day

$$TSS_{re} = FSS_{re} + X_{re} + BVSS_{re} \quad lbs/day \tag{A-159}$$

Effluent

$$TSS_e = (c)\ (Q_e)\ (8.34)\ (mg/L)\ (mgd) \quad lbs/day \tag{A-160}$$

Q_e See (A-198)

$$FSS_e = TSS_e \left(\frac{FSS_{re}}{TSS_{re}}\right) \quad lbs/day \tag{A-161}$$

$$X_e = TSS_e \left(\frac{X_{re}}{TSS_{re}}\right) \quad lbs/day \tag{A-162}$$

$$BVSS = TSS_e \left(\frac{BVSS_{re}}{TSS_{re}}\right) \quad lbs/day \tag{A-163}$$

$$RVSS_e = TSS_e \left(\frac{RVSS_{re}}{TSS_{re}}\right) \text{ lbs/day} \tag{A-164}$$

$$DBOD_{5_e} = (DBOD_{5_{re}})\ (Q_e)\ (8.34) \tag{A-165}$$

(mg/L) (mgd) lbs/day

$$SBOD_{5_e} = X_e \text{ lbs/day} \tag{A-166}$$

Underflow

Q_u See (A-147)

$$DBOD_{5_{re}} = (DBOD_{5_{re}})\ (Q_u)\ (8.34) \tag{A-167}$$

(mg/L) (mgd) lbs/day

$$SBOD_{5_u} = X_u \text{ See (A-170) lbs/day} \tag{A-168}$$

$$FSS_u = FSS_{re} - FSS_e \text{ lbs/day} \tag{A-169}$$

$$X_u = X_{re} - X_e \text{ lbs/day} \tag{A-170}$$

$$BVSS_u = BVSS_{re} - BVSS_e \text{ lbs/day} \tag{A-171}$$

$$RVSS_u = RVSS_{re} - RVSS_e \text{ lbs/day} \tag{A-172}$$

Where:

subscript o = influent (thickened sludge)
subscript re = reactor
subscript e = effluent
subscript u = underflow
h = ratio of underflow rate to feed flow rate = 0.60
c = concentration (mg/L) TSS_e
k = maximum rate of substrate removal per unit of biomass = 5.0 days^{-1}
K_s = substrate concentration at which removal rate is k/e = 60 mg/L.
Y = yield coefficient 0.6 mg VSS/mg BOD_5
b = fractional decay rate = 0.06 days^{-1}
g = substrate that cannot be broken down within mean cell residence time = 0.23

f = ratio of fixed to volatile solids = 0.11

p = mg BOD_5/mg biomass = 1.0

a = fraction of delayed biomass remaining = 0.23

d = fractional RVSS decay rate = 0.01 day^{-1}

Q_c = sludge age = 25 days

Dewatering--A dewatering model was developed and used for all thickening and dewatering (VF, C, SB, BF, etc.) operations. Since these are physical operations no material was destroyed or created (except for those processes that utilize chemical conditioning).

Dewatering is a physical process which removes as much of the free water as possible from the thickened or digested sludges. This results in a significant reduction in volume and also produces a material which is usually a semi-solid/solid which can be handled easier.

The following equations make up the dewatering model and are used in the order in which they appear.

Feed to the operational unit is either primary or combined (primary plus secondary) sludges (thickening) or digested sludges (dewatering).

$$Q_u = Q_o \left[\frac{C_o - C_e}{C_u - C_e}\right] \text{ gpd} \qquad \text{(A-173)}$$

$$Q_e = Q_o - Q_u \text{ gpd} \qquad \text{(A-174)}$$

$$DBOD_{5_o} = \frac{DBOD_{5_o}}{(Q_o)\ (8.34)} \qquad \frac{(\text{lbs/day})}{\text{mgd}} \text{ mg/L} \qquad \text{(A-175)}$$

$$TSS_o = FSS_o + X_o + BVSS_o + RVSS_o (\text{mg/L})\ (\text{mgd}) \qquad \text{(A-176)}$$

Effluent

Q_e See (A-174)

$$TSS_e = C_e\ (Q_e)\ (8.34) \quad \text{lbs/day} \qquad \text{(A-177)}$$

$$FSS_e = TSS_e \frac{FSS_o}{TSS_o} \quad \text{lbs/day} \qquad \text{(A-178)}$$

$$X_e = TSS_e \left(\frac{X_o}{TSS_o}\right) \quad \text{lbs/day} \qquad \text{(A-179)}$$

$$BVSS_e = TSS_e \left(\frac{BVSS_o}{TSS_o}\right) \quad \text{lbs/day} \qquad \text{(A-180)}$$

$$RVSS_e = TSS_e \left(\frac{RVSS_o}{TSS_o}\right) \quad \text{lbs/day} \qquad \text{(A-181)}$$

$$SBOD_{5_e} = X_e \quad \text{lbs/day} \qquad \text{(A-182)}$$

Underflow

Q_u See (A-173)

$$DBOD_{5_u} = \underset{\text{(mg/L)}}{(DBOD_{5_o})}\ \underset{\text{(mgd)}}{(Q_u)}\ (8.34) \quad \underset{\text{lbs/day}}{} \qquad \text{(A-183)}$$

$$FSS_u = FSS_o - FSS_e \quad \text{lbs/day} \qquad \text{(A-184)}$$

$$X_u = X_o - X_e \quad \text{lbs/day} \qquad \text{(A-185)}$$

$$BVSS_u = BVSS_o - BVSS_e \quad \text{lbs/day} \qquad \text{(A-186)}$$

$$RVSS_u = RVSS_o - RVSS_e \quad \text{lbs/day} \qquad \text{(A-187)}$$

$$SBOD_u = X_u \quad \text{lbs/day} \qquad \text{(A-188)}$$

Where:

subscript o = influent
subscript e = effluent
subscript u = underflow
C_e = concentration TSS_e
C_o = concentration TSS_o
C_u = concentration TSS_u

Note 1: C_O has to be adjusted to include those solids which will be added if chemicals (lime) are used as conditioners. This is accomplished by taking the pounds of chemicals added per pound of TSS, determining the quantity of liquid they will be contained in, and the known sludge characteristics and calculating a new concentration.

Note 2: Some of these operations require wash water. Where this is necessary the quantities and qualities have been determined and are returned just as if they were a separate sidestream.

Conditioning--A conditioning model was developed for sludge conditioning processes (e.g., HT, WAO, Purifax). These are physical processes which, in the case of the first two, do change the characteristics of the materials. In general, the solids are solubilized to $DBOD_5$, the percentage of solubilization being dependent on sludge characteristics and the process itself; solubilization has been assumed to be 0 for P_X.

Basically, conditioning is a process by which the sludge is sterilized; the cellular structure broken down to release the water entrained inside; and its dewaterability increased.

The following equations make up the conditioning model and are used in the order in which they appear.

Feed to the process unit is digested sludges (HT and WAO) and underflow from the primary and secondary clarifiers (P_X).

$$TSS_o = FSS_o + X_o + BVSS_o + RVSS_o \text{ lbs/day} \quad \text{(A-189)}$$

TSS_o destroyed by following priority: (A-190)

1. X_o
2. $BVSS_o$
3. $RVSS_o$

Material is removed from each category until total quantity is reached. For example, TSS_o destroyed = 300 lbs.

Original $TSS_o = 350$

$FSS_o = 20$

$X_o = 85$

$BVSS_o = 120$

$RVSS_o = 125$

After destruction

$FSS_{re} = 20$
$X_{re} = 0$
$BVSS_{re} = 0$
$RVSS_{re} = 30$

$$Q_u = Q_o \left[\frac{C_o - C_e}{C_u - C_e}\right] \qquad \text{(A-191)}$$

$$Q_e = Q_o - Q_u \qquad \text{(A-192)}$$

Solids Balance

Effluent

$$TSS_e = (C_e)\ (Q_e)\ (8.34)\ (\text{mg/L})\ (\text{mgd}) \qquad \text{(A-193)}$$

$$TSS_{re} = FSS_{re} + X_{re} + BVSS_{re} + RVSS_{re} \ \text{lbs/day} \qquad \text{(A-194)}$$

$$FSS_{re} = TSS_e \left(\frac{FSS_{re}}{TSS_{re}}\right) \ \text{lbs/day} \qquad \text{(A-195)}$$

$$X_e = TSS_e \left(\frac{X_{re}}{TSS_{re}}\right) \ \text{lbs/day} \qquad \text{(A-196)}$$

$$BVSS_e = TSS_e \left(\frac{BVSS_{re}}{TSS_{re}}\right) \ \text{lbs/day} \qquad \text{(A-197)}$$

$$RVSS_e = TSS_e \left(\frac{RVSS_{re}}{TSS_{re}}\right) \ \text{lbs/day} \qquad \text{(A-198)}$$

Underflow

$$FSS_u = FSS_{re} - FSS_e \quad \text{lbs/day} \qquad \text{(A-199)}$$

$$X_u = X_{re} - X_e \quad \text{lbs/day} \qquad \text{(A-200)}$$

$$BVSS_u = BVSS_{re} - BVSS_e \quad \text{lbs/day} \qquad \text{(A-201)}$$

$$RVSS_u = RVSS_{re} - RVSS_e \quad \text{lbs/day} \qquad \text{(A-202)}$$

BOD_5 Balance

$$TBOD_{5_e} = (TBOD_5)\ (Q_e)\ (8.34) \qquad \text{(A-203)}$$

(mg/L) (mgd) lbs/day

$$TBOD_{5_u} = (TBOD_5)\ (Q_u)\ (8.34) \qquad \text{(A-204)}$$

(mg/L) (mgd) lbs/day

$$SBOD_{5_o} - X_o = BOD_5 \text{ due to BVSS} \qquad \text{(A-205)}$$

$$\frac{BOD_5 \text{ due to BVSS}}{BVSS_o} = R \qquad \text{(A-206)}$$

$$SBOD_{5_e} = (R)\ (BVSS_o) \qquad \text{(A-207)}$$

$$SBOD_{5_u} = (R)\ (BVSS_u) \qquad \text{(A-208)}$$

$$DBOD_{5_e} = TBOD_{5_e} - SBOD_{5_e} \qquad \text{(A-209)}$$

$$DBOD_{5_u} = TBOD_{5_u} - SBOD_{5_u} \qquad \text{(A-210)}$$

Where:

subscript o = influent
subscript re = reactor
subscript e = effluent
subscript u = underflow
a = percent TSS_o destroyed
C_o = concentration (mg/L) TSS_o
C_e = concentration (mg/L) TSS_e
C_u = concentration (mg/L) TSS_u
$TBOD_5$ = concentration (mg/L) $TBOD_5$ assumed

TABLE A-2. INFLUENT CHARACTERISTICS (WITHOUT SIDESTREAM RECYCLE)

Parameter	Flow mgd	Concentration mg/L	Loading Lbs/Day
$TBOD_5$	1.0	220	1,835
$DBOD_5$	1.0	77	642
$SBOD_5$	1.0	143	1,193
TSS	1.0	220	1,835
FSS	1.0	55	459
X	1.0	0	0
BVSS	1.0	110	917
RVSS	1.0	55	459

TABLE A-3. MODEL REQUIREMENTS--SECONDARY TREATMENT

System	Effluent TSS mg/L	Secondary Clarifier Underflow TSS mg/L
Activated Sludge	20	not required
Trickling Filter	20	30,000
Rotating Biological Contactor	20	25,000

TABLE A-4. MODEL REQUIREMENTS--DIGESTION

Sidestream Generator	Treatment Combination	Decant TSS mg/L
Anaerobic Digestion		
	P	3,000
	P+AS	3,700
	P+TF	3,900
	P+RBC	3,900
Aerobic Digestion		
	All	5,000

TABLE A-5. MODEL REQUIREMENTS--CONDITIONING

Sidestream Generator	Treatment Combination	Percent Solubilized %	Decant TSS Concentration mg/L	Underflow TSS Concentration mg/L
Heat Treatment				
	P	35	2,500	135,000
	P+AS	45	3,000	110,000
	P+TF	40	2,750	115,000
	P+RBC	40	2,750	115,000
Wet Air Oxidation				
	P	75	2,500	135,000
	P+AS	85	3,000	110,000
	P+TF	80	2,750	115,000
	P+RBC	80	2,750	115,000
Purifax				
	All	Not applicable	100	Not applicable

Table A-5

TABLE A-6. MODEL REQUIREMENTS--DEWATERING

Sidestream Generator	Treatment Combination	Anaerobic Digestion		Aerobic Digestion		Washwater			Chemicals Added
		Sidestream TSS	Dewatered Sludge TSS	Sidestream TSS	Dewatered Sludge TSS	Flow	Washwater TSS		
		mg/L	mg/L	mg/L	mg/L	gpd	mg/L	lbs/lb.	
Vacuum Filter									
	P	2,000	280,000	N/A	N/A	2,400	1,000	0.156	
	P+AS	4,000	200,000	3,250	250,000	2,400	1,000	0.225	
	P+TF	4,000	235,000	N/A	N/A	2,400	1,000	0.155	
	P+RBC	4,000	235,000	N/A	N/A	2,400	1,000	0.155	
Basket Centrifuge									
	P	5,000	65,000	N/A	N/A	N/A	N/A	N/A	
	P+AS	1,750	100,000	900	140,000	N/A	N/A	N/A	
	P+TF	1,750	110,000	N/A	N/A	N/A	N/A	N/A	
Solid B. Stroll Centr.									
	P	6,000	250,000	N/A	N/A	N/A	N/A	N/A	
	P+AS	7,000	200,000	3,000	80,000	N/A	N/A	N/A	
	P+TF	6,500	225,000	N/A	N/A	N/A	N/A	N/A	
	P+RBC	6,500	225,000	N/A	N/A	N/A	N/A	N/A	

TABLE A-6. (continued)

Sidestream Generator	Treatment Combination	Anaerobic Digestion		Aerobic Digestion		Washwater		Chemicals Added
		Sidestream TSS	Dewatered Sludge TSS	Sidestream TSS	Dewatered Sludge TSS	Flow	Washwater TSS	
		mg/L	mg/L	mg/L	mg/L	gpd	mg/L	lbs/lb.
Belt Filter Press	P	1,000	300,000	N/A	N/A	3.500	300	N/A
	P+AS	2,500	250,000	1,700	135,000	3.500	300	N/A
	P+TF	2,000	275,000	N/A	N/A	3.500	300	N/A
	P+RBC	2,000	275,000	N/A	N/A	3.500	300	N/A
Sand Bed	P	180	120,000	N/A	N/A	N/A	N/A	N/A
	P+AS	180	120,000	150	150,000	N/A	N/A	N/A
	P+TF	180	120,000	N/A	N/A	N/A	N/A	N/A
	P+RBC	180	120,000	N/A	N/A	N/A	N/A	N/A
Lagoon	P	360	300,000	N/A	N/A	N/A	N/A	N/A
	P+AS	360	300,000	360	300,000	N/A	N/A	N/A
	P+TF	360	300,000	N/A	N/A	N/A	N/A	N/A
	P+RBC	360	300,000	N/A	N/A	N/A	N/A	N/A
Pressure Filter	P	120	400,000	N/A	N/A	200	2,000	0.17
	P+AS	250	350,000	20	350,000	200	2,000	0.32
	P+TF	125	350,000	N/A	N/A	200	2,000	0.26
	P+RBC	125	350,000	N/A	N/A	200	2,000	0.26

TABLE A-7. MODEL REQUIREMENTS--THICKENING (DEWATERING)

Sidestream Generator	Treatment Combination	Overflow TSS Conc. mg/L	Underflow TSS Concentration mg/L
Gravity Thickener	P+AS	300	50,000
	P+TF	300	70,000
	P+RBC	300	65,000
Dissolved Air Flotation	P+AS	250	68,000
	P+TF	200	65,000
	P+RBC	200	65,000

The following is a brief description of the procedure used in the sidestream characterization process:

1. Influent to POTW is feed to P; P underflow and overflow quantities and qualities calculated.
2. Overflow from P is feed to AS; sludge wasted and overflow quantities and qualities calculated.
3. Underflow from P and sludge wasted from AS combined to form feed to GT; overflow (sidestream) and underflow quantities and qualities calculated.
4. Thickened sludge from GT is feed to AnD; decant (sidestream) and digested sludge quantities and qualities calculated.
5. Digested sludge feed to VF; filtrate (sidestream) and dewatered sludge quantities and qualities calculated.
6. Sidestream flows and loadings are summed and added to original POTW influent to form new POTW influent.
7. Above processes repeated until steady state was reached.

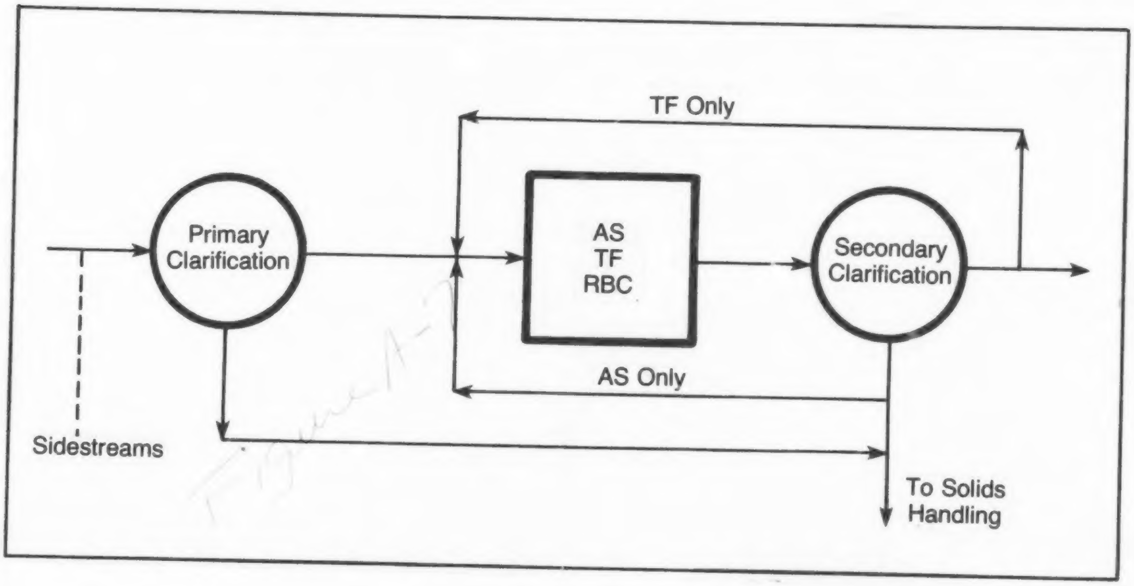
TF Only
Primary Clarification
AS
TF
RBC
Secondary Clarification
AS Only
Sidestreams
To Solids Handling
Figure A-7

Figure A-7. Mainstream Treatment Processes.

It was found that after three iterations steady state conditions were reached; the values calculated during the third iteration were less than one percent different from those calculated during the second iteration.

This process was performed for each of the "typical" wastewater treatment process flow schemes. Each sidestream was characterized according to flow (gpd), SS (mg/L and lbs/day), and BOD_5 (mg/L and lbs/day). The results of these steady state characterization calculations are presented in Table 8 (page 31). The characteristics are presented by sidestream generator and the wastewater treatment process flow scheme in which it appears.

Ranking Equation

General--

Although the sidestreams were characterized in the previous subsection, their relative importance with respect to predicted impact is yet to be determined. This type of problem -- determination of relative importance -- is an ideal application for indexing. Indexing is a method by which a number of related species can be compared using a fixed set of parameters. When index values are calculated they have no real value other than to serve as place holders. While one species has a value higher than another the only conclusion that can be drawn is that it should be placed above the other on a ranking list and not that it is two or three times more significant.

Equation--

General--The following equation was developed to index the sidestream generators according to the mainstream treatment process with which they are associated:

$$SII_j = \frac{\frac{\overline{Q}_{RP_j}}{\overline{Q}_{OP}} \quad \frac{2\overline{X}_{R_j}}{\overline{X}_O} + 1 + \frac{\overline{S}_{R_j}}{\overline{S}_O} \quad (NIU_j \cdot \overline{Q}_{O_j}) \quad (K \cdot COQ + COS \cdot \overline{S}_{R_j} \cdot C + COX \cdot \overline{X}_{R_j} - C)}{(POP)\ (\%\ Served)\ (COS \cdot \overline{S}_{OP} + COX \cdot \overline{X}_{OP} + COQ \cdot K \cdot \overline{Q}_{OP})}$$

Where:

SII_j = Sidestream impact index of j^{th} sidestream.

$\overline{Q}_{RP_j}$ = Average gallon per capita per day returned from j^{th} sidestream.

$\overline{Q}_{OP}$ = Average gallon per capita per day to POTW (100 gpcpd).

$\overline{X}_{R_j}$ = Average suspended solids returned from j^{th} sidestream.

$\overline{X}_O$ = Average influent suspended solids to POTW; (220 mg/L).

K = Cost conversion factor such that COQ = COS; 2×10^{-3}.

$\overline{S}_{R_j}$ = Average BOD_5 returned from j^{th} sidestream.

$\overline{S}_O$ = Average influent BOD_5; (220 mg/L).

NIU_j = Number of j^{th} processes in use.

$\overline{Q}_{O_j}$ = Average influent flow to POTW's with j^{th} sidestream.

COQ = Cost of treating 1 gallon of influent.

COS = Cost of treating 1 pound of BOD_5.

COX = Cost of treating 1 pound of suspended solids.

C = Constant; $\frac{8.34}{10^6}$

POP = USA population; (2×10^8).

% Serv= Percent of population served by POTW; (0.75)

$\overline{S}_{OP}$ = Average influent population equivalent BOD_5; (0.1835)

$\overline{X}_{OP}$ = Average influent population equivalent suspended solids (0.1835).

From the above list of parameters it can be seen that the only variables with respect to sidestream generator are $\overline{Q}_{RP_j}$, $\overline{X}_{R_j}$, $\overline{S}_{R_j}$, NIU_j, $\overline{Q}_{O_j}$, COQ, COS, and COX.

Q_{RP_j}--The Q_{RP_j} factor is the average gallon per capita per day returned from the j^{th} sidestream flow (gpd) obtained from Table 8, Summary of Sidestream Characteristics, divided by $\overline{Q}_{O_j} \times 10^4$.

For example, flow treatment scheme P + AS + GT + AnD + VF from Table 8 average sidestream flow for VF = 4,933. From Table A-10, $\overline{Q}_{Oj} = 5.998$.

$$Q_{RP_j} = \frac{4,933}{5.998 \times 104} = 0.082$$

$\overline{X}_{R_j}$ and $\overline{S}_{R_j}$--The $\overline{X}_{R_j}$ amd $\overline{S}_{R_j}$ factors are the average suspended solids and BOD_5 returned from the j^{th} sidestream in mg/L. These values are obtained from Table 8. It must be remembered that they are averages.

For example, VF sidestream in P + AS + GT + AnD + VF

$$\overline{X}_{R_j} = \frac{389 + 406 + 794}{3} = 530 \text{ mg/L}$$

$$\overline{S}_{R_j} = \frac{2,260 + 2,360 + 2,210}{3} = 2,400 \text{ mg/L}$$

NIU_j and $\overline{Q}_{oj}$--The NIU_j and $\overline{Q}_{oj}$ factors for the prioritization equation were calculated from population distributions and needs survey data from NTIS (53), EPA (112) and the University of Tennessee (108). The NIU_j factor is the number of j^{th} sidestream generating processes in use, and the $\overline{Q}_{oj}$ factor is the average influent flow (to the POTW) of plants with the j^{th} sidestream generating process.

The process for calculating NIU_j and $\overline{Q}_{oj}$ can best be illustrated by the following example for heat treatment. Referring to Table A-8, all data were distributed according to population group. The population groups, the flow generated, and the average flow in mgd were arranged as shown in Table A-9.

The 1978 Needs Survey Data from EPA (112) indicates that the total number of wastewater treatment plants in the United States is 17,377. Figures from the University of Tennessee (108) show that the total number of plants could be distributed with respect to population group, as shown in Column 2 of Table A-8. The distribution in Column 3 of Table A-8, the probability of P_j that the plant has the j^{th} sidestream, was obtained from vendor's literature (14). The figures in Column 4 were obtained

TABLE A-8. CALCULATION OF NIU_j AND $\overline{Qo}_j$ FOR HEAT TREATMENT

	①	②	③	④	⑤
Population Group	Size Qoj (MGD)	NoP No. Plants in US	Probability Plant has jth Sidestream P_j	NIU_j P_j × Total # Units	= 4 × 1 NoP × P_j = NIU_j × Qo_j
1	0.25	504	0.0364	6	2
2	0.75	678	0.109	19	14
3	1.75	678	0.273	46	81
4	3.75	6,082	0.345	59	220
5	7.50	3,910	0.0727	12	93
6	17.50	2,954	0.109	19	324
7	37.50	1,599	0.0182	3	12
8	50.00	972	0.0364	6	309
		17,377		④ = 170	⑤ = 1,055

TOTAL # UNITS = 170 (=NIU_j)

$$\frac{⑤}{④} = \overline{Qo}_j = \frac{1055}{170} = 6.21$$

TABLE A-9. POPULATION DISTRIBUTION

Population Group	Population Range	Flow Generated[(1)] (gpd)	Average Flow for Population Group (MGD)
1	Under 5,000	Under 500,000	0.25
2	5,000 - 10,000	500,000 - 1,000,000	0.75
3	10,000 - 25,000	1,000,000 - 2,500,000	1.75
4	25,000 - 50,000	2,500,000 - 5,000,000	3.75
5	50,000 - 100,000	5,000,000 - 10,000,000	7.5
6	100,000 - 250,000	10,000,000 - 25,000,000	17.5
7	250,000 - 500,000	25,000,000 - 50,000,000	37.5
8	500,000 and over	50,000,000 and over	50.0

Notes:

(1) - Flow generation rate = 100 gpcd

by multiplying the value of P_j for each population group by the total number of units (in this case, 170). The values in Column 5 were calculated by multiplying each value in Column 4 by the corresponding value in Column 1. The factor $\overline{Qo}_j$ was then computed by dividing the sum of the figures in Column 5 by the sum of the figures in Column 4.

The same NOP distribution was used for all processes. In other words, the distribution used in Column 2 was the same for all processes, because the population distribution of the total number of plants in the U.S. is the same, regardless of the process used. However, several different distributions were used in Column 3 depending on the process in question. Table A-10 summarizes the NIU_j data, the $\overline{Qo}_j$ calculated, and the Column 3 distribution used for each process.

The Purifax distribution was used for both heat treatment and wet air oxidation, since no distributions were available specifically for either process and since it was thought that the size and type of POTW which would use Purifax might have used heat treatment or wet air oxidation instead.

No distribution was available specifically for aerobic digestion, so the distribution for executed aeration was used as an approximation, since extended aeration and aerobic digestion are used together in a number of plants treating flows from relatively small populations.

COQ, COS, and COX--All cost figures were taken from reference. The objective was to develop cost estimates for operation and maintenance (O&M) of each unit operation/process in a given process train, with the ultimate objective of calculating cost factory (COX, COS, and COQ) for use in the prioritization equation. O&M costs included labor, materials, power, and (if required) chemicals, and all costs were based on mgd flow.

Reference gave cost estimates for several process trains which included activated sludge and trickling filters, but no costs were given for process trains with rotating biological contactors (RBC's), heat treatment, or wet air oxidation. Costs were given, however, for individual unit operations/processes such as RBC's, heat treatment, and wet air oxidation.

When O&M costs given for the process trains were compared with the sum of costs given for the components of the train, it was found that costs for the process trains were somewhat higher than the sum of costs for each of the components of the train. The reason for the difference in cost is that the system cost includes the costs for miscellaneous structures (administrative offices, laboratories, shop and garage facilities).

TABLE A-10. SUMMARY OF NIU_j DATA, $\overline{Qo}_j$, AND DISTRIBUTION

Heat Treatment	170(53)	6.21	Purifax(14)
Wet Air Oxidation	13(53)	6.85	Purifax(14)
Single-Stage Anaerobic	4,171(112)	2.41	Table 9, "Separate Digestion"(53)
Two-Stage Anaerobic	742(112)	3.90	Table 9, "Two Stage Digestion"(53)
Aerobic Digestion	4,750(112)	1.72	Table 7, "Extended Aeration"(53)
Vacuum Filtration	1,912(112)	5.998	Table 9, "Mechanical Dewatering"(53)
Filter Press	157(112)	6.006	Table 9, "Mechanical Dewatering"(53)
Belt Filter	132(112)	6.50	Table 9, "Mechanical Dewatering"(53)
Centrifuge	368(112)	6.12	Table 9, "Mechanical Dewatering"(53)
Sand Bed	10,939(112)	1.65	Table 9, "Sand Beds" (53)
Purifac	69(53)	6.89	Purifax (14)
Gravity Thickening	940(112)	5.98	Table 9, "Mechanical Dewatering"(53)
Lagoon	314(112)	5.86	Table 9, "Mechanical Dewatering"(53)

Table A-10

In order to obtain component costs on an equal basis with system costs, the individual component costs in a system were multiplied by the ratio of the system cost to the sum of the component costs.

Costs for each system were then apportioned among the cost to handle flow, the cost to treat BOD, and the cost to treat SS, in order to calculate the unit treatment cost factors (COX, COS, and COQ) to use in the prioritization equation. Assuming a 1-mgd flow, a 100-gpcd wastewater generation rate (i.e., population = 10,000), and influent SS and BOD_5 concentrations of 220 mg/L each, the daily loadings on the plant are 0.1835 lbs SS per capita per day, and 0.1835 lbs BOD_5 per capita per day. It was also assumed that the cost to treat BOD equals the cost to treat flow and that the cost to treat SS is twice the cost to treat BOD. In addition, it was estimated that the cost to treat 100 gallons (the daily per capita flow rate) was $50, and that the cost to treat the daily per capita BOD loading (0.1835 lbs) was also $50. Therefore, the cost to treat the daily per capita SS loading (0.1835 lbs) was $100.

If the cost to treat 100 gallons was $50, then the cost to treat one gallon was $0.50. Similarly, the cost to treat one pound of BOD was $272.50, and the cost to treat one pound of SS was $545.

The annual costs to treat 1-mgd flow with BOD and SS concentrations of 220 mg/L each were calculated as follows:

		% of Total Annual Treatment Cost for Treatment of Constituent
Annual Cost to Treat Flow	= $182,500,000	25%
Annual Cost to Treat BOD	= 182,493,795	25%
Annual Cost to Treat SS	= 364,987,590	50%
	$729,981,385	100%

Therefore, of the total cost for treatment, 50 percent is for SS treatment, 25 percent for BOD treatment, and 25 percent for handling flow.

The portion of the total annual system cost attributable to treatment flow, BOD, and SS was calculated for each process train by taking 25 percent of the total for BOD and flow, and 50 percent for SS treatment. Then the annual treatment cost factors (COX, COS, and COQ) used in the prioritization equation were calculated by dividing the BOD portion and the SS portion of the total annual system cost by the annual BOD or SS loading (365 days/yr) (k mgd) (8.34) (220 mg/L) and by dividing the flow-portion of the total annual system cost by the total annual flow (365 days) (1,000,000 gal/day).

Summary of Ranking

Through use of the indexing equation and methodology presented for determining variables, the sidestream generators were indexed with respect to their impact on POTW's. It should be noted that the values are place holders and qualitative rather than quantitative. The data input to the indexing equation have been summarized and are presented in Table A-11. The results of the indexing have been summarized and are presented in Table A-12.

This indexing was undertaken to indicate to the user of this document which sidestream generators have been predicted to have a greater impact on a POTW. This is to be used as an aid when it is impossible to correct all sidestream impacts and some decision must be made as to which one should be approached first.

TABLE A-11. SIDESTREAMS INDEXING INPUT

Stream No.	Description	COS ($x10^{-2}$)	COX ($x10^{-3}$)	COQ ($x10^{-4}$)	QAP (10^{-2})	X_R	S_R	Number in Use	Q_{OJ}	SII
1	HT-P	5.50×10^{-2}	110	1.01	2.68	2,500	6,500	9	6.21	8.51×10^{-10}
2	WAO-P	6.06×10^{-2}	121	1.11	2.73	2,500	7,500	0	6.85	0
3-4	AnD-P	2.71×10^{-2}	54.3	0.50	3.44	3,000	732	264	2.64	4.72×10^{-9}
5	VF-P	3.60×10^{-2}	72.0	0.66	5.79	1,310	254	37	6.00	4.80×10^{-10}
6	FP-P	3.93	78.6	0.72	2.20	404	331	3	6.01	2.58×10^{-12}
7	BF-P	3.81	76.2	0.70	8.79	434	124	8	6.50	2.32×10^{-11}
8	C-P	3.58	71.5	0.66	3.01	5,000	2,570	7	6.12	8.72×10^{-11}
9	SB-P	3.12	62.4	0.57	5.23	150	357	277	1.65	5.81×10^{-11}
10	PX-P	4.86	97.1	0.89	2.74	100	200	4	6.89	7.90×10^{-13}
11	HT-P/AS	6.47	129	1.19	23.0	3,000	6,500	112	6.21	1.07×10^{-7}
12	WAD-P/AS	7.02	140	1.29	21.4	3,000	7,500	12	6.85	1.37×10^{-8}
13-14	AnD-P/AS	3.81	76.2	0.70	7.38	3,700	832	4,150	2.64	2.37×10^{-7}
15	AeD-P/AS	3.59	71.8	0.66	4.84	5,000	1,030	4,060	1.72	1.77×10^{-7}
16	VF-P/AS	4.62	92.3	0.85	8.22	2,400	530	1,430	6.00	8.75×10^{-8}
17	FP-P/AS	4.94	98.8	0.91	4.32	315	265	107	6.01	1.17×10^{-10}
18	BF-P/AS	4.82	96.4	0.88	20.7	744	210	83	6.50	1.53×10^{-9}
19	C-P/AS	4.59	91.8	0.84	2.97	5,670	1,120	266	6.12	3.22×10^{-8}
20	SB-P/AS	4.15	82.9	0.76	11.4	170	275	8,210	1.65	3.36×10^{-9}
21	PX-P/AS	5.78	116	1.06	17.9	100	200	53	6.89	6.81×10^{-11}
22	GT-P/AS	3.53	70.5	0.65	16.0	300	157	687	5.98	2.05×10^{-9}
23	DAF-P/AS	3.65	73.0	0.67	17.2	250	136	234	5.86	5.40×10^{-10}
24	LA-P/AS	4.15	82.9	0.76	2.59	360	480	529	6.32	6.21×10^{-10}
25	HT-P/TF	6.52	130	1.20	4.92	2,750	6,500	47	6.21	8.86×10^{-9}
26	WAD-P/TF	7.08	142	1.30	5.22	2,750	7,500	1	6.85	2.59×10^{-10}
27-28	AnD-P/TF	3.79	75.8	0.70	4.19	3,900	818	2,270	2.64	8.06×10^{-8}
29	VF-P/TF	4.62	92.3	0.85	6.48	1,980	461	416	6.00	1.39×10^{-8}
30	FP-P/TF	4.95	98.9	0.91	2.90	318	261	41	6.01	3.00×10^{-11}
31	BF-P/TF	4.83	96.5	0.89	13.0	564	160	26	6.50	1.79×10^{-10}
32	C-P/TF	4.59	91.8	0.84	2.13	6,500	1,160	81	6.12	9.06×10^{-9}
33	SB-P/TF	4.13	82.7	0.76	6.48	170	281	2,290	1.65	5.39×10^{-10}
34	PX-P/TF	5.81	116	1.07	4.50	100	200	17	6.89	3.89×10^{-12}
35	GT-P/TF	3.50	70.0	0.64	1.99	300	189	214	5.98	8.54×10^{-11}
36	DAF-P/TF	3.63	72.6	0.67	1.39	200	84	71	5.86	8.00×10^{-12}
37	LA-P/TF	4.13	82.7	0.76	1.46	360	480	225	6.32	1.49×10^{-10}
38	HT-P/RBC	7.25	145	1.33	5.65	2,750	6,500	2	6.21	4.33×10^{-10}
39	WAD-P/RBC	7.81	156	1.43	5.70	2,750	7,500	0	6.85	0
40-41	AnD-P/RBC	4.54	90.8	0.83	4.44	3,900	839	115	2.64	4.34×10^{-9}
42	VF-P/RBC	5.36	107	0.98	6.59	2,010	478	32	6.00	1.13×10^{-9}
43	FP-P/RBC	5.69	114	1.04	3.03	306	263	6	6.01	4.41×10^{-12}
44	BF-P/RBC	5.57	111	1.02	13.6	567	168	15	6.50	1.06×10^{-10}
45	C-P/RBC	5.34	107	0.98	2.25	6,500	1,180	14	6.12	1.66×10^{-9}
46	SB-P/RBC	4.88	97.6	0.90	6.90	170	282	159	1.65	4.00×10^{-11}
47	PX-P/RBC	6.54	131	1.20	5.11	100	200	0	6.89	0
48	GT-P/RBC	4.25	85.0	0.78	2.28	300	187	22	5.98	1.00×10^{-11}
49	DAF-P/RBC	4.38	87.5	0.80	2.00	200	94	5	5.86	8.72×10^{-13}
50	LA-P/RBC	4.88	97.6	0.90	1.48	360	480	14	6.32	9.37×10^{-12}

TABLE A-12. SUMMARY OF INDEXING RESULTS

Priority	Stream Number	Description	Value	Cumulative Value	%
31	21	PX - P/CMAS	86	998,436	99.98
32	9	SB - P	73	998,509	99.98
33	46	SB - P/RBC	51	998,560	99.99
34	30	FP - P/TF	38	998,598	99.99
35	7	BF - P	29	998,627	99.99
36	48	GT - P/RBC	13	998,640	100
37	50	LA - P/RBC	12	998,652	100
38	36	DAF -P/TF	10	998,662	100
39	43	FP - P/RBC	6	998,668	100
40	34	PX - P/TF	5	998,673	100
41	6	FP - P	3	998,676	100
42	10	PX - P	1	998,677	100
43	49	DAF - P/RBC	1	998,678	100
44	2	WAO - P	0	998,678	100
45	39	WAO - P/RBC	0	998,678	100
46	47	PX - P/RBC	0	998,678	100

P - Primary Clarifier
AS - Activated Sludge
TF - Trickling Filter
RBC - Rotating Biological Contactor
GT - Gravity Thickener
DAF - Dissolved Air Flotation Thickener
AnD - Anaerobic Digestion
AeD - Aerobic Digestion
VF - Vacuum Filter
C - Centrifuge
BF - Belt Filter Press
SB - Sand Drying Beds
LA - Lagoon
FP - Pressure Filter (Filter Press)
HT - Heat Treatment
WAO - Wet Air Oxidation
PX - Purifax

TABLE A-12. (continued).

Priority	Stream Number	Description	Value	Cumulative Value	%
1	13-14	An-D - P/CMAS	300,000	300,000	30.04
2	15	Ae-D - P/CMAS	220,000	520,000	52.07
3	11	HT - P/CMAS	140,000	660,000	66.09
4	16	VF - P/CMAS	110,000	770,000	77.10
5	27-28	AnD - P/TF	100,000	870,000	87.12
6	19	C - PCMAS	41,000	911,000	91.22
7	29	VF - P/TF	18,000	929,000	93.02
8	12	WAO - P/CMAS	17,000	946,000	94.73
9	32	C - P/TF	11,000	957,000	95.83
10	25	HT - P/TF	11,000	968,000	96.93
11	3-4	AnD - P	6,000	974,000	97.53
12	40-41	AnD - P/RBC	5,500	989,000	98.08
13	20	SB - P/CMAS	4,200	983,000	98.50
14	22	GT - P/CMAS	2,600	986,000	98.76
15	45	C - P/RBC	2,100	988,000	98.97
16	18	BF - P/CMAS	1,900	990,300	99.16
17	42	VF - P/RBC	1,400	991,700	99.30
18	9	C - P	1,100	992,800	99.41
19	1	HT - P	1,100	993,900	99.52
20	24	LA - P/CMAS	790	994,690	99.60
21	23	DAF - P/CMAS	680	995,370	99.67
22	33	SB - P/TF	680	996,050	99.74
23	5	VF - P	610	996,660	99.80
24	28	HT - P/RBC	550	997,210	99.85
25	26	WAO - P/TF	330	997,540	99.89
26	31	BF - P/TF	230	997,770	99.91
27	37	LA - P/TF	190	997,960	99.93
28	17	FP - P/CMAS	150	998,110	99.94
29	44	BF - P/RBC	130	998,240	99.96
30	35	GT - P/TF	110	998,350	99.97

APPENDIX B

APPLICATION EXAMPLE

GENERAL

An example illustrating the use of the material presented in Sections 2, 3, 4, and 5 is included in this subsection. The intent of this information is to provide the user with a means of evaluating suspected sidestreams problems and, if confirmed, provide operational and/or design methods that the user can implement to mitigate the impact of sidestreams.

The following example is a hypothetical situation that is intended to be used as a guide. Since no two treatment plants are alike, it is impractical to attempt to prepare examples for each treatment system configuration. It is anticipated that the user will modify or tailor the information presented in this subsection to conform to the individual facility.

BACKGROUND

Treatment Plant Flow Pattern

A flow diagram indicating the selected flow path for this example is presented in Figure B-1. As can be seen on the diagram, the treatment system consists of the following major units:

1. Primary clarification.
2. Secondary treatment - activated sludge.
3. Gravity thickening.
4. Anaerobic sludge digestion.
5. Vacuum filtration.

The secondary clarifier was considered as part of the secondary treatment process.

Design Conditions

Selected design conditions for the example treatment system are summarized and presented in Table B-1. This information generally should be available for all treatment systems, and is usually found in the facility's operations and maintenance manual and on design drawings for the facility.

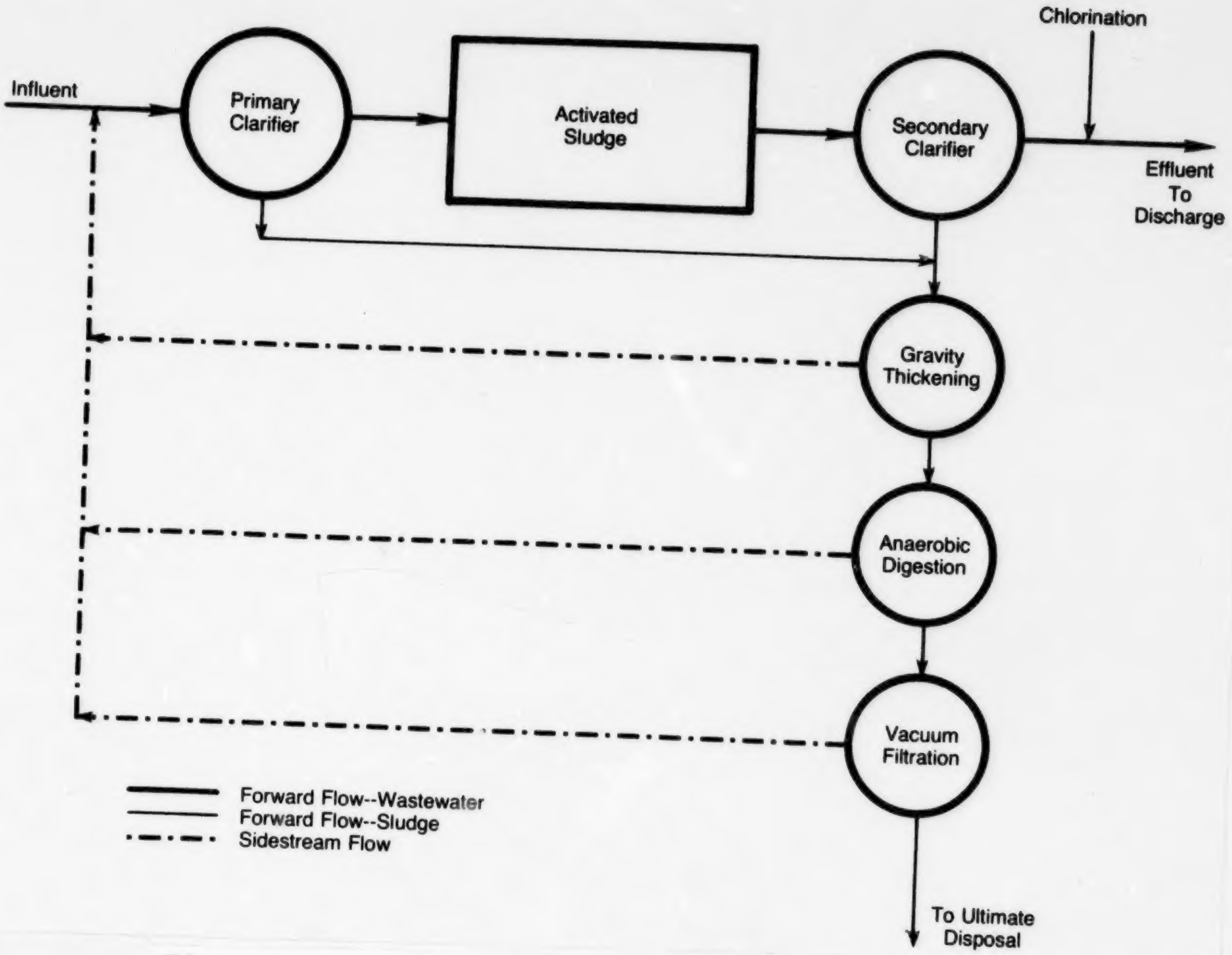
Influent
Primary Clarifier
Activated Sludge
Secondary Clarifier
Chlorination
Effluent To Discharge
Gravity Thickening
Anaerobic Digestion
Vacuum Filtration
To Ultimate Disposal
Forward Flow--Wastewater
Forward Flow--Sludge
Sidestream Flow

Figure B-1. Selected example flow path.

TABLE B-1. EXAMPLE--DESIGN CONDITIONS, SUMMARY OF MAJOR EQUIPMENT

Primary Clarifiers	
Number	2
Diameter	110 ft
Weir Overflow Rate	24,000 g/ft
Solids Loading Rate*	.06 lb/hr/ft^2*
Primary Sludge Pumps	
Number	2
Type	Constant Rate
Rated Output	150 gpm ea
Secondary Treatment-Activated Sludge	
Solids Loading	10,000 lbs/day
Hydraulic Loading (Detention Time) - 0% Return	4.5 hours
BOD$_5$ Loading	15,600 lbs/day
Secondary Clarifiers	
Solids Loading Rate	.6 lbs/hr/ft^2
Surface Loading Rate	600 gpd/ft^2
Sludge Waste Rate Output	0-300 gpm
Gravity Thickeners	
Number	3
Solids Loading Rate	8 lbs/ft^2/day
Hydraulic Loading (Detention Time)	375 gpd/ft^2
Digester Feed Pumps	
Number	3
Type	Constant Rate
Rated Output	300 gpm
Anaerobic Digestion (2 stage)	
Solids (volatile) Loading Rate	.04 - 0.1 lbs VSS/ft^3
Hydraulic Loading (Detention Time)	30 - 60 days
Vacuum Filtration	
Number	1-Coil
Loading Rate	5 lbs/ft^2/hr
Surface Area	500 ft^2
Feed Pump Rated Output	0-100 gpm

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*Calculated value. Not a normal design parameter for primary clarifiers.

Using the Evaluation Algorithms

A prerequisite to the use of the evaluation algorithms is that a monitoring program has been implemented and that the required information is available for use when using the evaluation algorithms. The first step in the procedure is to refer to the Evaluation Algorithm associated with the first mainstream process unit; in this case, the Primary Clarification Evaluation Algorithm.

Monitoring Program Data

For purposes of this example, data is presented in Table B-2 which summarizes the results of the monitoring program performed on the example treatment facility (also see Table 3).

Primary Clarification

Refer to the Primary Clarification Evaluation Algorithm presented in Figure 4. The evaluation is initiated at location ①.

The primary clarifier effluent suspended solids concentration was determined to be 150 mg/L as shown in Table B-2. The primary effluent quality is worse than would normally be expected (approximately 100 mg/L), thus requiring a further evaluation (i.e., "Yes" on Figure 4, moving the reader to location ③).

Solids Loading (location ①)--

From Table B-1 the influent design solids loading is given as 0.06 lb/hr/ft^2.

The design loading is compared to the solids loadings applied to the clarifiers with and without sidestreams returning in order to rule out problems that may not be related to sidestreams. An example calculation of the solids loading (w/o sidestreams) is shown below.

Calculation of Solids Loading W/O Sidestreams

$$\begin{aligned}
&\text{Solids Loading (lbs/hr/ft}^2\text{)} \\
&\text{(two clarifiers in use)}
\end{aligned}
\begin{aligned}
&= \frac{\text{Influent lbs solids/day}}{\text{24 hr/day x (clarifier surface area, ft}^2\text{)}} \\
&= \frac{\text{200 mg/L x 8.34 lbs/gal x 15 mgd}}{\text{24 hr/day x 9,500 ft}^2\text{ x 2}} \\
&= \frac{\text{25,020 lbs/day}}{\text{456,000 hr/ft}^2\text{/day}} \\
&= \text{0.055 lbs/hr/ft}^2
\end{aligned}$$

TABLE B-2. EXAMPLE--SUMMARY OF MONITORING PROGRAM DATA

Influent	Without Sidestreams	With Sidestreams
Flow (mgd)	15	16.5
TSS (mg/L)	200	300
BOD$_5$ (mg/L)	200	350
pH	6.8	7.3
DO (mg/L)	1.2	
Primary Clarifier		
Eff. Flow (mgd)	14.975	16.475
Eff. TSS (mg/L)	80	150
Eff. BOD$_5$ (mg/L)	125	245
Eff. DO (mg/L)	0.7	0.2
Eff. pH	6.5	7.2
Sludge Pumping Rate (gpm)	300	-
Sludge Pumping Frequency	1/day	-
Sludge Pumping Duration (min)	90	-
Sludge TSS (mg/L)	50,000	-
Secondary-Activated Sludge		
Mixed Liquor DO (mg/L)	2.5	.75
DO Uptake (mg/L/hr)	18	27
MLSS (mg/L)	2,700	3,200
Sludge Waste Rate (gpm)	300	-
Sludge Waste Duration (min)	30	-
Sludge Waste Frequency	1/hr	-
Sludge TSS (mg/L)	10,000	-
Final Eff. Flow (mgd)	-	16.26
Final Eff. SS (mg/L)	-	55
Final Eff. BOD$_5$ (mg/L)	-	47
Final Eff. pH	-	6.3

TABLE B-2. (continued)

Sidestreams Data

Gravity Thickeners	Unit No. 1	Unit No. 2	Unit No. 3
Overflow BOD (mg/L)	275	400	400
Overflow TSS (mg/L)	300	700	700
Overflow Rate (gpm)	600	300	300
Dilution Water Rate (gpm)	300	-	-
Underflow Rate (gpm)	300	300	300
Underflow Duration (min)	75	90	90
Underflow Frequency	1/day	1/day	1/day
Underflow TSS (mg/L)	60,000	30,000	30,000

Anaerobic Digester (2 stage)	
Supernatant TSS (mg/L)	3,700
Supernatant Flow Rate (gpm)	500
Supernatant Duration (min)	80
Supernatant Flow Frequency	1/day
Supernatant BOD$_5$ (mg/L)	850
Sludge Feed VSS (lb/day)	21,050
Sludge Feed Rate (gpm)	300
Sludge Feed Duration (min)	255
Digested Sludge TSS	55,000

Vacuum Filters (2)	
Filtrate TSS (mg/L)	5,000
Filtrate Flow Rate (gpm)	80
Filtrate Flow Duration (hrs)	6.5
Filtrate Flow Frequency	1/day (4 days/week)
Filtrate Flow BOD$_5$	530
Filtrate pH	12.5
Cake Quantity	2,500 lbs dry/hr
Cake % Solids	20

The calculations for solid loading w/sidestreams is done in a similar manner.

A comparison of the loading rates is shown in Table B-3.

Table B-3

Comparison of Loading Rates

	Design	W/O Sidestreams	W/Sidestreams
Loading Rate ($lbs/hr/ft^2$)	0.06	0.055	0.091

As can be seen by comparison of these loading rates (④, ⑧), the loading rate w/o sidestreams returning is less than the design rate, and the loading rate w/sidestreams returning is greater than the design. Therefore, solids loading of the sidestreams causes the design condition to be exceeded and may be partly or wholly responsible for observed poor performance of the primary clarifiers. At this point in the evaluation, we have finished steps ⑦ and ⑧, and are at location ⑨. As we have yet to implement operational methods, we go to ⑪ and continue the evaluation. However, if we had exhausted operational methods to reduce the impact of the sidestream, we would implement design methods and be referred to $\boxed{1}$ which would refer to the 1 location of Table 10, Alternative Design Modifications for Primary Clarification (PC). Following implementation of the appropriate design modifications, we would return to location ⑫ of Figure 4.

At this point, the user should refer to the Mainstream Evaluation Checklist (Table 4) and place a check in the Control Required column associated with primary clarification solids loading. Continue with the evaluation.

Hydraulic Loading (location ⑫)--
The influent design hydraulic loading given in Table B-1 is 24,000 gal/ft (weir overflow rate).

The design hydraulic loading is compared to the hydraulic loadings applied to clarifiers with and without sidestreams returning to the system. The hydraulic loadings can be calculated by following the example given.

Calculation of Hydraulic Loading W/O Sidestreams

Hydraulic Loading (gpd/ft)
(Weir Overflow Rate)
(two clarifiers in use)

$$= \frac{\text{Influent flow (gpd)}}{\text{Weir length (ft)}}$$

$$= \frac{14{,}975{,}000 \text{ gals/day}}{314 \text{ ft} \times 2}$$

$$= 23{,}850 \text{ gpd/ft}$$

The calculation of hydraulic loading w/sidestreams is done in a similar manner.

A comparison of the hydraulic loading rates is shown in Table B-4.

Table B-4

Comparison of Hydraulic Loading Rates

	Design	W/O Sidestreams	W/Sidestreams
Loading Rate (gpd/ft)	23,880	23,850	26,230

The comparison of these loading rates (⑭ , ⑱)indicates that sidestream flows are responsible for exceeding the design hydraulic loading rate of the primary clarifiers. This condition may be partially or wholly responsible for observed poor performance of the primary clarifiers. Operational and/or design methods must be implemented to reduce the impact.

Refer to the Mainstream Evaluation Checklist and check the Control Required column associated with hydraulic loading. Continue with the evaluation.

Dissolved Oxygen (location ㉒)--
The dissolved oxygen concentrations reported in Table B-2 for the primary clarifier effluent are compared (㉓ , ㉗). The comparison indicates that the sidestream flows cause a depression in the DO concentration below an acceptable limit of

0.5 mg/L. This condition may be partially or wholly responsible for the observed poor performance of the primary clarifiers. Operational and/or design methods must be implemented to reduce the impact.

Refer to the Mainstream Evaluation Checklist and check the Control Required column associated with dissolved oxygen concentration. Continue with the evaluation.

At this point in the evaluation (location ㉛), the user is asked if any implementation steps are required that have not been previously implemented. The answer to the question at this time will be YES. The user is directed to implement applicable operational control methods.

The user should not implement control methods until all of the evaluations are completed and until the recommended control methods are reviewed for applicability for the specific POTW.

The control methods are summarized in separate algorithms that are classified according to methods that are available at the mainstream (Mainstream Operational Control Methods) and methods that are available at the sidestream generator (Sidestream Operational Control Methods). The user should refer to the evaluation checklist to determine the location of the control algorithm(s), upon completion of the evaluations.

In this example, the user is referred to the Operational Mainstream Control Algorithm block designated by ①. The use of this algorithm is discussed in a later subsection of the example. Continue with the evaluation.

Secondary Treatment-Activated Sludge

Refer to location ㊵ of the activated sludge algorithm that appears as Figure 5.

The secondary effluent suspended solids and BOD_5 concentrations are greater than 35 mg/L (as shown in Table B-2, 55 mg/L and 47 mg/L, respectively). Since the effluent concentrations of BOD_5 and SS exceed acceptable limits (35 mg/L and 35 mg/L), the sidestream impact evaluation is merited.

Hydraulic Loading (Forward Flow Rate, location ㊸)--
From Table B-1, the design secondary treatment forward flow rate is given as 15 mgd.

The design hydraulic loading is compared to hydraulic loadings applied to the secondary activated sludge system with and without sidestreams returning to the system. The hydraulic loadings can be calculated by following the example given.

Calculation of Hydraulic Loading W/O Sidestreams

Forward flow = Influent flow* - (Primary sludge flow + Sidestream flow)

= 17.5 mgd - (0.025 mgd + 2.5 mgd)

= 14.975 mgd

*This example (and algorithm) assumes that the influent flow is measured after sidestreams reenter the plant influent. If the forward flow is measured before the sidestreams re-enter, the calculation becomes:

Forward flow = Influent flow - Primary sludge flow (w/o sidestreams)

A comparison of the forward flow (㊸, ㊼) rates is shown in Table B-5.

Table B-5

Comparison of Forward Flow Rates

	Design	W/O Sidestream	W/Sidestream
Forward flow rate, mgd	15	14.975	17.475

The comparison of these forward flow rates indicates that sidestream flows are responsible for exceeding the design forward flow rate of the secondary system. This condition may be partially or wholly responsible for the observed poor performance of the secondary treatment system.[1] Operational and/or design methods must be implemented to reduce the impact (location ㊾ , ㊿).

Refer to the Mainstream Evaluation Checklist and check the Control Required column associated with hydraulic loading. Continue with the evaluation.

pH (location (51))--
The pH values reported in Table B-2 for the primary clarifier effluent are compared. The comparison indicates that the sidestream flows do not change the forward flow pH conditions beyond acceptable limits. No control action is required. Continue with the evaluation.

Dissolved Oxygen (location (60))--
The dissolved oxygen concentration in the aeration basin is used as an indicator to determine whether the BOD$_5$ and/or SS sidestreams impacts are substantial enough to require corrective action.

The dissolved oxygen concentration normally maintained in the aeration basin is compared to the dissolved oxygen concentration in the basin after the sidestreams reenter the system. The comparison of the dissolved oxygen concentrations presented in Table B-2 indicates that aeration basin DO is depressed from 2.5 mg/L to 0.75 mg/L. Evaluations of the BOD$_5$ and SS sidestreams impacts are justified. Continue with the evaluation.

Solids Loading (location (67))--
The solids loading applied to the secondary system is considered excessive if the suspended solids concentration in the secondary influent exceeds 100 mg/L. The reported value as shown in Table B-2 indicates that the secondary influent (primary clarifier effluent) is 150 mg/L -- far exceeding the 100 mg/L limit. This condition may be partially or wholly responsible for the observed poor performance of the secondary treatment system. Operational and/or design methods must be implemented (location (69) , (70)).

---

[1] Realistically, it is not only important to note that the forward flow rate (w/sidestreams) exceeds the design rate, but it is also important to consider how much it exceeds the design rate. The increase due to sidestreams exceeds the design rate by almost 17 percent and clearly requires corrective action.

Refer to the Mainstream Evaluation Checklist and check the Control Required column associated with solids loading. Continue with the evaluation.

BOD$_5$ Loading (location (71))--
The BOD$_5$ loading applied to the secondary system is considered excessive if the BOD$_5$ concentration in the secondary influent exceeds 160 mg/L. The reported value as shown in Table B-2 indicates that the secondary influent (primary clarifier effluent) is 245 mg/L -- far exceeding the 160 mg/L limit. This condition may be partially or wholly responsible for the observed poor performance of the secondary treatment system. Operational and/or design methods must be implemented (location (73) , (74)).

Refer to the Mainstream Evaluation Checklist and check the Control Required column associated with BOD$_5$ loading. Continue with the evaluation.

At this point, location (75) , (as with primary clarifiers), the user is asked if any implementation steps are required that have not been previously implemented. The answer to the question at this time will be YES. The user is directed to proceed to the applicable operational control methods. The locations of the applicable operational control algorithms can be found to the right of the checked diamonds on Table B-6, which is a partially completed Evaluation Algorithm Checklist for this example. The impacts that have been determined in the course of evaluating the primary clarifier and activated sludge systems are summarized on this checklist.

USING THE MAINSTREAM OPERATIONAL CONTROL ALGORITHMS

The Mainstream Operational Control Algorithms are intended to be used after an evaluation is made of the mainstream processes.

Primary Clarification

As a result of the evaluation the user was directed to ⟨1⟩ of the Primary Clarifier Control Algorithm. The Primary Clarification Control Algorithm (Figure 7) presents methods that can be used to control sidestream impacts at the primary clarifiers; however, all methods do not apply for all facilities. The user must review those methods recommended and determine what methods apply for the given POTW. A checklist is provided for the user to keep a tally of those methods that apply to the POTW (Table B-7).

TABLE B-6. EVALUATION ALGORITHM CHECKLIST (ORIGINALLY TABLE 4)

	1		2		3		4	
	Control	Required	Section Number	Page Number	Is Design Modification Required		Section Number	Page Number
Primary Clarification								
Solids Impact		1	4	54		1	6	103
Hydraulic Impact		1	4	54		2	6	103
Dissolved Oxygen		1	4	54		3	6	103
Activated Sludge								
Hydraulic Impact		10	4	56		10	6	104
pH Impact						11	6	104
Solids Impact		19	4	59		12	6	104
BOD_5 Impact		25	4	60		13	6	104
Trickling Filter								
Hydraulic Impact		40	4	63		20	6	105
pH Impact						21	6	105
Solids Impact		43	4	63		22	6	105
BOD_5 Impact		43	4	63		23	6	105
RBC								
Hydraulic Impact		62	4	65		30	6	105
pH Impact						31	6	105
Solids Impact		60	4	65		32	6	105
BOD_5 Impact		60	4	65		33	6	105

TABLE B-7. CONTROL ALGORITHM CHECKLIST (ORIGINALLY TABLE 5)

Place a Check ◇✓ In the Appropriate Box

	Address		Action Statement	Does This Action Apply To The POTW? YES	Does This Action Apply To The POTW? NO	Check When Applicable Action Taken
Primary Clarification						
	1	◇	Maintain Low Sludge Blanket	✓		
	3 or 5	◇	Reduce Variability in Sludge Removal	✓		
Activated Sludge	14	◇	Dampen Influent Flow Surges	✓		
	15	◇	Dampen Effluent Flow Surges		✓	
	18	◇	Maintain Low Sludge Blanket	✓		
	20	◇	Increase Aeration Output	✓		
	22	◇	Utilize Flocculant Aids		✓	
	26	◇	Increase Aeration Output - See 20		✓	
	29	◇	Increase Recycle Rate During Shock Load	✓		
	30	◇	Adjust Waste Sludge Rate	✓		
	31	◇	Reduce Variability in Sludge Removal	✓		
Trickling Filter	42 or 45	◇	Adjust Recycle to Forward Flow Ratio			
	46	◇	Force Ventilate Filter Bed			
	48	◇	Utilize Flocculant Aids			

TABLE B-7. (continued)

	Address		Action Statement	Does This Action Apply To the POTW? YES	Does This Action Apply To the POTW? NO	Check When Applicable Action Taken
RBC	49	◇	Reduce Variability in Sludge Removal			
	50	◇	Maintain Low Sludge Blanket			
	61	◇	Increase Rotational Speed			
	63	◇	Dampen Influent Flow Surges			
	65	◇	Utilize Flocculant Aids			
	66	◇	Reduce Variability in Sludge Removal			
	67	◇	Maintain Low Sludge Blanket			
Gravity Thickening	81	◇	Eliminate or Minimize Dilution Water	✓		
	87	◇	Blend Sludges	✓		
	89	◇	Utilize Flocculant Aids		✓	
	90	◇	Reduce Detention Time	✓		
	92	◇	Redirect Flow to Grit Chamber	✓		
	93	◇	Minimize Clarifier Detention Time-See 1, 18, 50, 67	✓		
	94	◇	Reduce Overflow Variability-See 3, 5, 31, 49, or 66	✓		
	94	◇	Reduce Underflow Variability	✓		

TABLE B-7. (continued)

	Address	Action Statement	Does This Action Apply To The POTW? YES	 NO	Check When Applicable Action Taken
DAF					
	102	◇ Reduce Variability in Sludge Feed			
	103	◇ Utilize Flocculant Aids			
	104	◇ Clean Packing			
	105	◇ Minimize Cake Inventory			
	106	◇ Minimize Settled Solids			
Anaerobic Digestion	110	◇ Reduce Variability in Sludge Feed-See 94	✓		
	113	◇ Reduce Variability in Sludge Removal	✓		
	114 or 116	◇ Reduce Variability in Supernatant Removal	✓		
	115	◇ Minimize Sludge Inventory	✓		
	117	◇ Redirect Flow to Thickener		✓	
	122	◇ Correct Digester Loading		✓	
	125	◇ Correct Digestion Performance	✓		
Aerobic Digestion	130	◇ Allow Proper Settling Time			
	131	◇ Reduce Variability in Supernatant Removal			

TABLE B-7. (continued)

	Address		Action Statement	Does This Action Apply To The POTW? YES	Does This Action Apply To The POTW? NO	Check When Applicable Action Taken
	132	◇	Reschedule Supernatant Removal			
	133	◇	Reduce Supernatant Removal Interferences			
Vacuum Filters	140	◇	Schedule Shutdown	✓		
	141	◇	Redirect Tank Drains to Thickeners		✓	
	142	◇	Schedule Cleaning	✓		
	143	◇	Redirect Filtrate to Thickeners		✓	
	145	◇	Neutralize pH		✓	
	147 or 151	◇	Optimize Cleaning			
	148	◇	Clean or Replace Springs	✓		
	149 or 152	◇	Optimize Chemical Conditioning	✓		
	155	◇	Change Filter Cloths	✓		
	156	◇	Stop Overflow		✓	
Centrifuges	160	◇	Schedule Shutdown	✓		
	161	◇	Redirect Tank Drains to Thickeners			
	162	◇	Redirect Centrate to Thickeners			

In the example case, the methods marked 1 and 5 apply to the facility and are checked on the example checklist.

Secondary Treatment Activated Sludge

As a result of the evaluation the user was directed to 10, 19 and 25 of the Activated Sludge Control Algorithm (Figure 8).

After evaluating the applicability of the control methods presented in this algorithm, it is determined that the methods marked 14, 18, 20, 29, and 31 apply for the example facility, whereas methods 15, 22, and 26 do not apply.

The required implemented actions for both primary and secondary treatment are summarized in Table B-8, at the end of this section. Once the changes are completed, the user should proceed as directed to the sidestream control algorithms that apply to the facility. The algorithms that apply to the example case include GT (Gravity Thickening), AnD (Anaerobic Digestion) and VF (Vacuum Filters). The use of these algorithms is now discussed.

USING THE SIDESTREAM CONTROL ALGORITHMS

The sidestream operational control algorithms are intended to be used after first utilizing the mainstream operational control algorithms. It is intended that the user select (from the list presented in the last box of the mainstream control algorithms) the appropriate sidestreams for the POTW. For example, see Figure 8 where one sees that the Gravity Thickener (GT) option refers the reader to 80. This procedure then continues with Figure 11, at 80. For the example case, these sidestreams include GT, AnD, and VF. These are discussed in the following subsections.

Gravity Thickening (GT)

Refer to the Gravity Thickening Control Algorithm (Figure 11).

The Gravity Thickening Control Algorithm presents methods that can be used to control sidestream impacts at the gravity thickeners; however, all methods do not apply for all facilities. The user must review those methods recommended and determine which apply for the given POTW. A checklist is provided for the user to keep a tally of those methods that apply to the POTW.

In this example case, the methods marked 81, 87, 90, 92, 93, and 94 apply to the facility and are checked on the example checklist (Table B-7).

Before implementing the applicable control methods, the user should continue with the remaining sidestream algorithms (AnD and VF).

Anaerobic Digestion (AnD)

Refer to the Anaerobic Digestion Control Algorithm (Figure 13).

The Anaerobic Digestion Control Algorithm presents methods that can be used to control sidestream impacts at the anaerobic digesters; however, all methods do not apply for all facilities. The user must review those methods recommended and determine which apply for the given POTW.

In the example case, the methods marked 110, 113, 114, 115, and 125 apply to the facility and are checked on the example checklist.

Before implementing the applicable control methods, the user should continue with the remaining sidestream algorithm (VF).

Vacuum Filtration (VF)

Refer to the Vacuum Filter Control Algorithm (Figure 15).

The Vacuum Filter Control Algorithm presents methods that can be used to control sidestream impacts at the vacuum filters; however, all methods do not apply for all facilities. The user must review those methods recommended and determine which apply for the given POTW.

In the example case, the methods marked 140, 142, 147, 148, 149, and 156 apply to the facility and are checked on the example checklist.

IMPLEMENTATION

All of the control methods indicated on the checklist must be implemented. As a practical matter, however, the methods cannot (and should not) be implemented simultaneously. The user should implement the control methods based on priorities and operating constraints that are specific to the POTW. Once all of the applicable methods are implemented, the user must return to the Mainstream Evaluation Algorithms and reevaluate the facility to determine whether the operational changes were successful in controlling the impact. Table B-8 illustrates the methods that were implemented in the example case in order to control the sidestream impacts.

This example case assumes that the operational methods that were implemented were successful in controlling the impacts and, consequently, no design modifications were required. Had operational modifications failed, however, the Evaluation Algorithms would have referred the manual user to the correct design modification algorithms, designated by □. From Table B-6, column 4, the user would be referred to the page of the appropriate design modification algorithm.

TABLE B-8. EXAMPLE IMPLEMENTATION SUMMARY

Location	Current Operating Condition	Required Change	Modified Operating Practice
Primary Clarifiers	Removing sludge @ 300 gpm for 90 min.-1/day	◇1 Maintain low sludge blanket ◇5 Reduce variability in sludge removal	Monitor depth change sludge removal to: 300 gpm for 30 min.-1/shift
Activated Sludge	Receiving flow surges blanket varies to 5 ft. aeration constant recycle constant	◇14 Dampen flow surges	Installed baffles at end of feed channels
	Blanket varies to 5 ft. or more	◇18 Maintain low sludge blanket	Adjust waste rate to compensate for BOD_5/S.S. changes. Also adjusted recycle flow in response to flow changes.
	No adjustments made to aeration equipment	◇20 Increase aeration output	Increased blower output in response to increases in BOD_5/S.S.
	Recycle Rate is constant	◇29 Increase recycle rate during shock load	Monitoring D.O. uptake each shift, increasing recycle rate by 10% in response to 20% increase in uptake
	Wasting sludge @ 300 gpm for 30 min./hr.	◇31 Reduce variability in sludge removal	Changed waste rate to 150 gpm and continuously waste sludge
Gravity Thickeners	Using dilution water @ 300 gpm	◇81 Eliminate dilution water	Eliminated dilution water when an extra tank was removed from service and after sludges were blended

TABLE B-8 (continued).

Location	Current Operating Condition	Required Change	Modified Operating Practice
Gravity Thickeners (cont'd)	Segregated sludge thickening	87 Blend sludges	Evaluated blending in lab. Implemented after lab. data proved OK to do so.
	3 units in service	90 Reduce detention time	Removed 3rd unit from service after determining that remaining units would perform satisfactorily.
	Thickener overflow returning to primary clarifier (after grit chamber)	92 Redirect flow to grit chamber	Changed valving to redirect flow
	Maintaining large sludge inventory in the thickeners	93 Minimize detention time	Accomplished when changes made to primary pumping rate
	Intermittent pumping to and from the units cause overflow peaks	94 Reduce overflow and underflow variability	Accomplished practically when primary and secondary sludge pumping changed.
	Underflow pumping at 900 gpm for 75-90 min/day		Changed underflow pumping to 300 gpm for 90 minutes each shift
Anaerobic Digesters	Intermittent sludge feed	110 Reduce variability in sludge feed	Accomplished when thickener underflow pumping changed

TABLE B-8 (continued).

Location	Current Operating Condition	Required Change	Modified Operating Practice
Anaerobic Digesters (cont'd).	Supernatant removed 1/day @ 500 gpm for 80 min. Supernatant removed thru decant line.	◇114 Reduce variability in Supernatant Removal	Opened decant valve partially to maintain 100 gpm supernatant flow. Removed supernatant for approximately 2 hrs. each shift.
	Large sludge inventories maintain in secondary digesters. Vacuum filters operated 4 days per week.	◇115 Minimized sludge inventory	Began operating filters for 5 days per week then when inventory reduced, went back to 4 day per week schedule
	Digester receiving shock due to 1/day feed	◇125 Correct digester operation	Modified operation accomplished when thickener underflow pumping changed
Vacuum Filters	Chemical and sludge tanks full at end of production day requiring "dumps" into the drain	◇140 Schedule shutdown	Chemical and sludge usage from tanks estimated. Chemicals and sludge in tanks are paced to run out at the end of the production day
	Vacuum filters receive cursory cleaning daily. Thorough cleaning on weekends	◇142 Schedule cleaning	Thorough cleaning scheduled at the end of each shift

TABLE B-8 (continued).

Location	Current Operating Condition	Required Change	Modified Operating Practice
Vacuum Filters (cont'd)	Cleaning operation indescriminate	◇47 Optimize cleaning	Special attention paid to spring, seals, guide railers and drum surface
	Springs stretched out	◇48 Clean or replace springs	Acid cleaned springs. Replaced as required. Scheduled acid cleaning or regular basis
	Door floc. formation and poor solids capture	◇49 Optimize chemical conditioning	Performed tar tests and changed chemical dosages
	Sludge flowing into vat overflow	◇56 Stop overflow	Adjusted sludge and chemical feed rates and drum speed to maintain vat level below the overflow. Installed plug in overflow pipe just in case.